LIFE CYCLE ASSESSMENT - CENTER FOR INTERACTIVE RESEARCH ON SUSTAINABILITY (C I R S)

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CIVL 498E

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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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LIFE CYCLE ASSESSMENT - CENTER FOR INTERACTIVE RESEARCH ON SUSTAINABILITY (C I R S)

CIVIL 498E FINAL REPORT

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Abstract

The Centre for Interactive Research on Sustainability (CIRS) located on 2210 West Mall; is one of the greenest buildings in British Columbia at its time of construction - developed primarily in response to the challenge of creating a more sustainable society. The LCA study was completed at the request of UBC Social Ecological Economic Development Studies (SEEDS) to transparently communicate the environmental benefits of University's first net-zero energy and regenerative building and further pave the ways for similar future ventures. Although first of its kind study of a Green Building in UBC, CIRS LCA study is a part of UBC wide academic building LCA data repository and would contribute to knowledge built up of that database.

A formulated approach as per ISO 14044 standard, was adopted to complete the LCA study as comprehensively as possible. The approach was carried off from quantity take-off using different state-of-art software, to preparing as thorough an inventory of building components & assemblies as was possible from the available information, modeling was done with Athena Impact Estimator which has one of the largest life cycle inventory database in North America. Assumptions and limitations of the software as well as the data were document in order to make the process transparent for any future reference or comparisons, this included explicit documentation in the form of input and assumption documents appendix to this report.

From the analysis it is evident that CIRS stand up to the test of being sustainable and contributing positively towards its environment. Despite the challenges of whole building LCA study we are confident that this study would be a contribution towards knowledge built up and would encourage further such studies; strengthening the process and providing knowledge based information tool for future policies.

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1. INTRODUCTION

The Centre for Interactive Research on Sustainability (CIRS) located on 2210 West Mall; is one of the greenest buildings in British Columbia at its time of construction - developed primarily in response to the challenge of creating a more sustainable society. CIRS is a brain child of Professor John Robinson and took about 12 years and 3 major iterations to be a reality and a sustainability leader in regenerative – net zero building echelon. The building is designed in conjunction with UBC's living lab concept and acts in its own as a "living laboratory" & test bed, which allows research and investigation of current and future sustainable building technologies.

CIRS program was initiated in 2000 and went through several iterations- the final design was made by Busby Perkins +Will in 2006. It is a LEED Platinum certified building and also on review list of "The Living Building Challenge". CIRs was constructed with a total cost of $23 Million and was officially inaugurated in November 2011.

Figure 2 - Rendering Initial CIRS design

Figure 1 - Center for Interactive Research on Sustainability

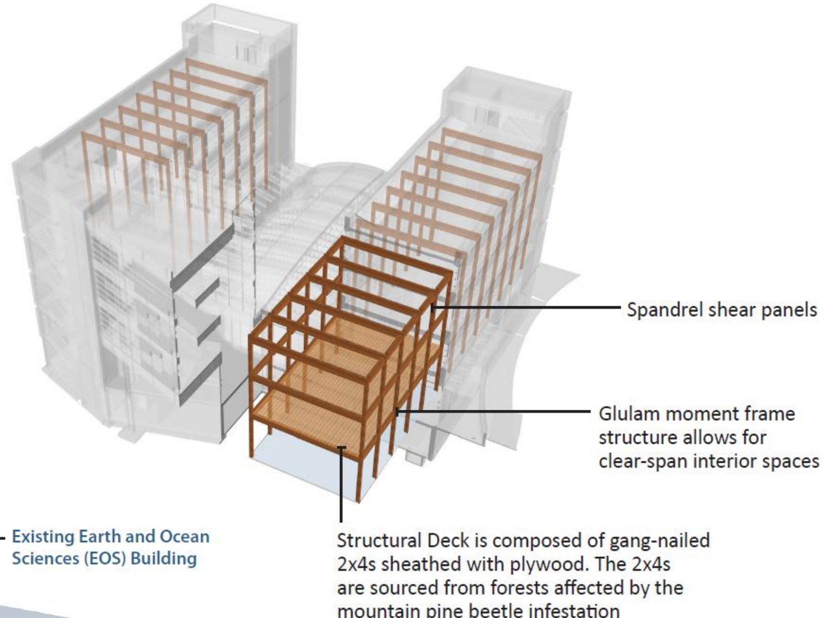
Figure 3 -

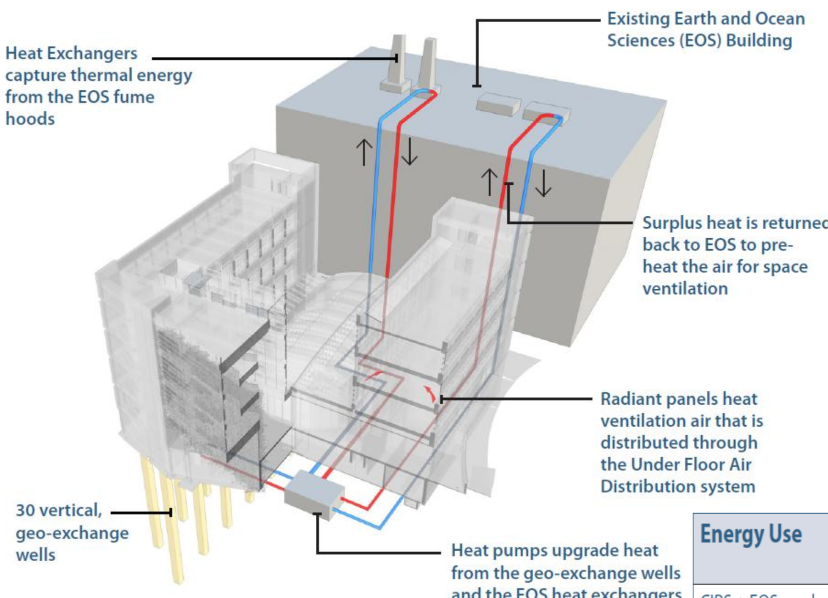
CIRS building is 5,675 m^2 (61,085 ft^2) on a site area of 2,008 m^2 (21,614 ft^2). The structure is comprised of a pair of four-storey office/lab blocks running east-west, linked by an atrium which acts as building lobby and entry to a 450-seat lecture auditorium for general campus use. The building accommodates a mix of academic office spaces, dry labs, meeting rooms, social spaces and service spaces, with building services, storage and locker facility, as well as electrical, mechanical and plumbing spaces in the basement.

The building is not designed to hold any particular discipline classes or lectures as in a typical institutional building; rather it was designed to accommodate a variety of different uses over the life of the building. The building mainly consists of open areas which are used for workstations, closed offices, dry lab space and meeting rooms.

Service and building systems spaces are located in the basement, including electrical rooms, pump rooms, potable water processing room and the main data and communication room. However, the most unique feature of the building is its *wastewater treatment system*, which is located in a glass volume on the ground floor.

Keeping up with its sustainability banner and “Wood First Act”; CIRS is the first large, multi-story institutional building at the UBC. The Structural system is constructed from Glulam framing system, supporting a solid wood deck. Over 50 per cent of the wood used in the project is certified by the Forest Stewardship Council (FSC) and the remaining is pine from forests affected by the Mountain Pine Beetles.





CIRS boasts a high-performance building envelope, passive design strategies, and provisions for occupant sensitive equipment but above all it has a one of a kind heat recovery system with Earth and Ocean Sciences (EOS) building.

Energy Use	Energy Consumed/Reduced (ekWhr/yr)
CIRS + EOS pre-heat system	613, 540
CIRS Heat Transfer to EOS	-622, 070
Total Savings at the UBC Plant	-1,036,783

Table 1 - Building Characteristics

Building System	Specific Building Characteristics
Structure	Wooden Moment Frame structure, Glulam Column-Beam
Floors	Structural Deck composed of gang-nailed 2x4s sheathed with plywood. Pine Beetle Wooden joists
Exterior Walls	Curtain walls, fenestrations in wooden framing
Interior Walls	Drywalls with wood & steel studs
Windows	Low emission argon filled glass windows
Roof	Wooden joist roof
Mechanical	Solar aquatic biofilter, hot air exchange system

2. Goal and Scope

Life Cycle Assessment described in this report follows the guidelines as per ISO 14044 (Canadian Standards Association, 2006), Section 4.2.2 and 4.2.3. The given goal and scope below is to clearly define the intent, frame work for suitable analysis and interpretation of the results to provide appropriate recommendations.

The purpose of defining the Goal of the study is to unambiguously state the context of the study, whereas the Scope details how the actual modeling of the study was carried out.

2.1 Goal of Study

The goals for LCA study of CIRS has been defined as per ISO 14044 parameters to explicitly illustrate the intent and context of the study.

2.1.1 Intended application

Describes the purpose of the LCA study.

This LCA study will be used in two ways:

- Conduct a study as a proof of concept for the sustainability claim of CIRS (LEED Platinum) by ascertaining the environmental impact footprint of this first-of-its-kind regenerative building.
- As a benchmark contribution of environmental impacts of a state-of-the-art sustainable regenerative building in the overall data-base repository of UBC academic buildings.
- Model developed for this study is intended to be a factual knowledge contribution and testing ground for newer tools of Life cycle inventory; for that will be used to create further avenues for future Green building LCA studies.

2.1.2 Reasons for carrying out the study

Describes the motivation for carrying out the study.

The LCA study was completed at the request of UBC Social Ecological Economic Development Studies (SEEDS) to transparently communicate the environmental benefits of University's first net-zero energy and regenerative building and further pave the ways for similar future ventures. Secondly, the report itself is an educational asset to help disseminate education on LCA and help further the development of this scientific method into sustainability in building construction practices at UBC and the green building industry. This study, therefore, contributes to a pool of knowledge for propagating LCA understanding and practices which are gaining acceptance at all scales of sustainable construction standards and corporate social responsibility policy.

2.1.3 Intended audience

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

The results of this study are to be primarily communicated to the public. In addition to the general public, the LCA report is intended as a knowledge benchmark to encourage researchers and practitioners to further develop LCA studies on sustainable green buildings.

2.1.4 Intended for comparative assertions

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

There were no comparative assertion made within the study of CIRS building, however as it is a part of a larger database, the study can be used for comparative assertions with other UBC building LCA studies.

The study is carried out for the sole purpose of contribution towards knowledge built-up for green buildings and future audience should be aware of the goals & scope of the study to make cognitive comparative assertions.

2.2 Scope of Study

The following are descriptions for a set of parameters that detail how the actual modeling of the study was carried out.

2.2.1 Product system to be studied

Describes the collection of unit processes that will be included in the study.

Collection of unit processes with elementary and product flows, performing one or more defined functions, and which models the life cycle of a product (ISO 14044). The main processes that make up the product system to be studied in this LCA study are the Construction Product Manufacturing (Figure 4), the Building Construction (Figure 5), the Energy Production (Figure 6) and Building Demolition (Figure 7). These four processes are the building blocks of the LCA models that have been developed to describe the impacts associated from CIRS Building. The unit processes and inputs and outputs considered within these three main processes are outlined below.

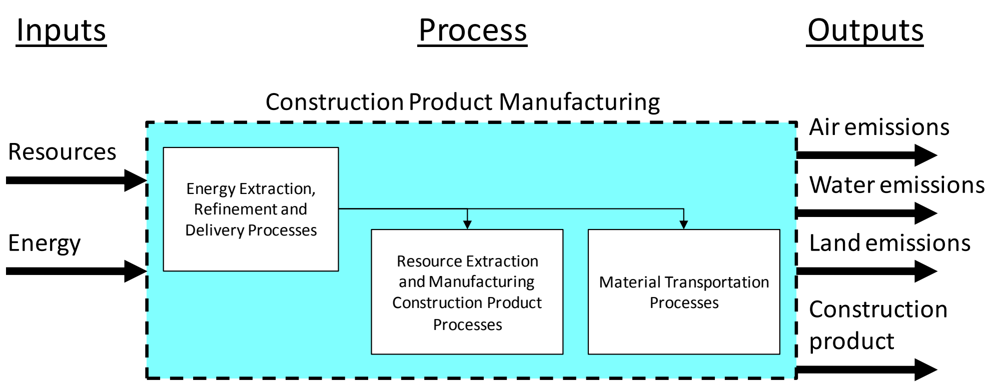


Figure 4 - Generic unit processes considered within Manufacturing Construction materials by Impact Estimator software.

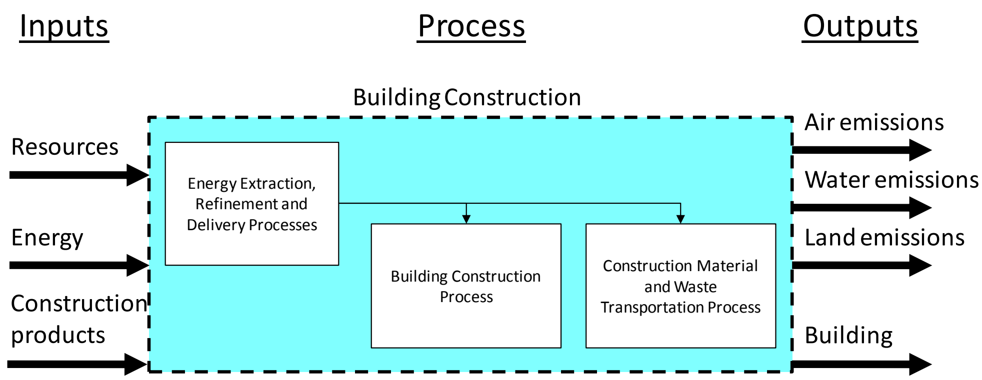


Figure 5 - Generic unit processes considered within Building Construciton by Impact Estimator software.

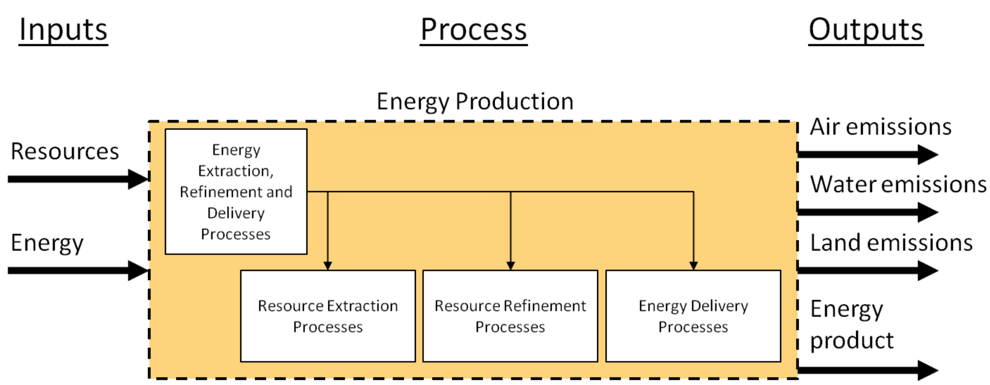


Figure 6 - Generic unit processes considered within Building Construciton by Impact Estimator software.

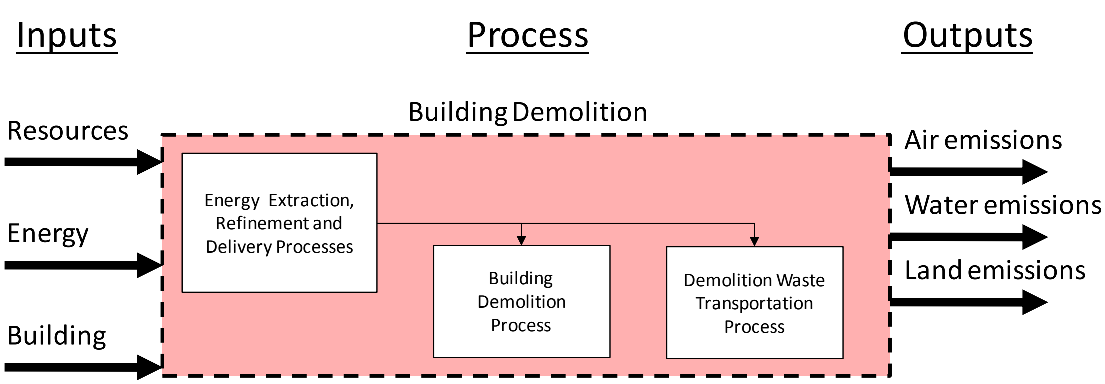


Figure 7 - Generic unit processes considered within Building Demolition process by Impact Estimator software.

As seen in the above figures, the inputs and outputs occurring at the various stages in a buildings life cycle are captured. That is, the building demolition unit process capture the grave (i.e. end of life) and the construction product manufacturing, energy production and building construction processes capture the cradle to gate (i.e. resource extraction, manufacturing construction products and construction of a building). System boundary defines the organization of the above process units to describe the impacts of construction of Green buildings.

2.2.2 System boundary

Details the extent of the product system to be studied in terms of product components, life cycle stages, and unit processes.

The ISO standards indicate that inputs to a product or process do not need to be included in an LCI if (1) they do not represent a significant fraction of the total mass of processed materials or product, (2) they do not contribute significantly to a toxic emission, and (3) they do not represent a significant amount of energy.

The selection of the system boundary shall be consistent with the goal of the study (ISO 14044); for the LCA study of CIRS we are only modeling processes from construction product manufacturing till building demolishment. Any processes beyond and after our system boundary see Figure 8, is not part of this study and such should be well understood prior to any comparative assertions with other products with varied boundary conditions. The LCA models developed to describe the impacts were created in the Impact Estimator software "Athena EI" using the unit processes, within the main processes, illustrated previously in Figure 4, Figure 5, Figure 6 and Figure 7.

As the LCA study is carried out for a building; which in itself consists of myriad of different products, making a complex array of different constituent product assemblies and their associated process units. Further, this also highlights the need to define the materials for those constituent products in order to have a thorough and complete study of life cycle of the building (main product).

The product components (product assemblies) which all contribute towards the main product (i.e. building) are: footings, slabs on grade, walls, columns and beams, roofs, doors and windows, gypsum board, vapour barriers, insulation, cladding and roofing. Further materials like Concrete, Steel, wood, glass, polystyrene etc make the constituent of each of the above assemblies and are the main contributors of any of the environmental impact footprints associated with the product assemblies and subsequently the building (CIRS in our case).

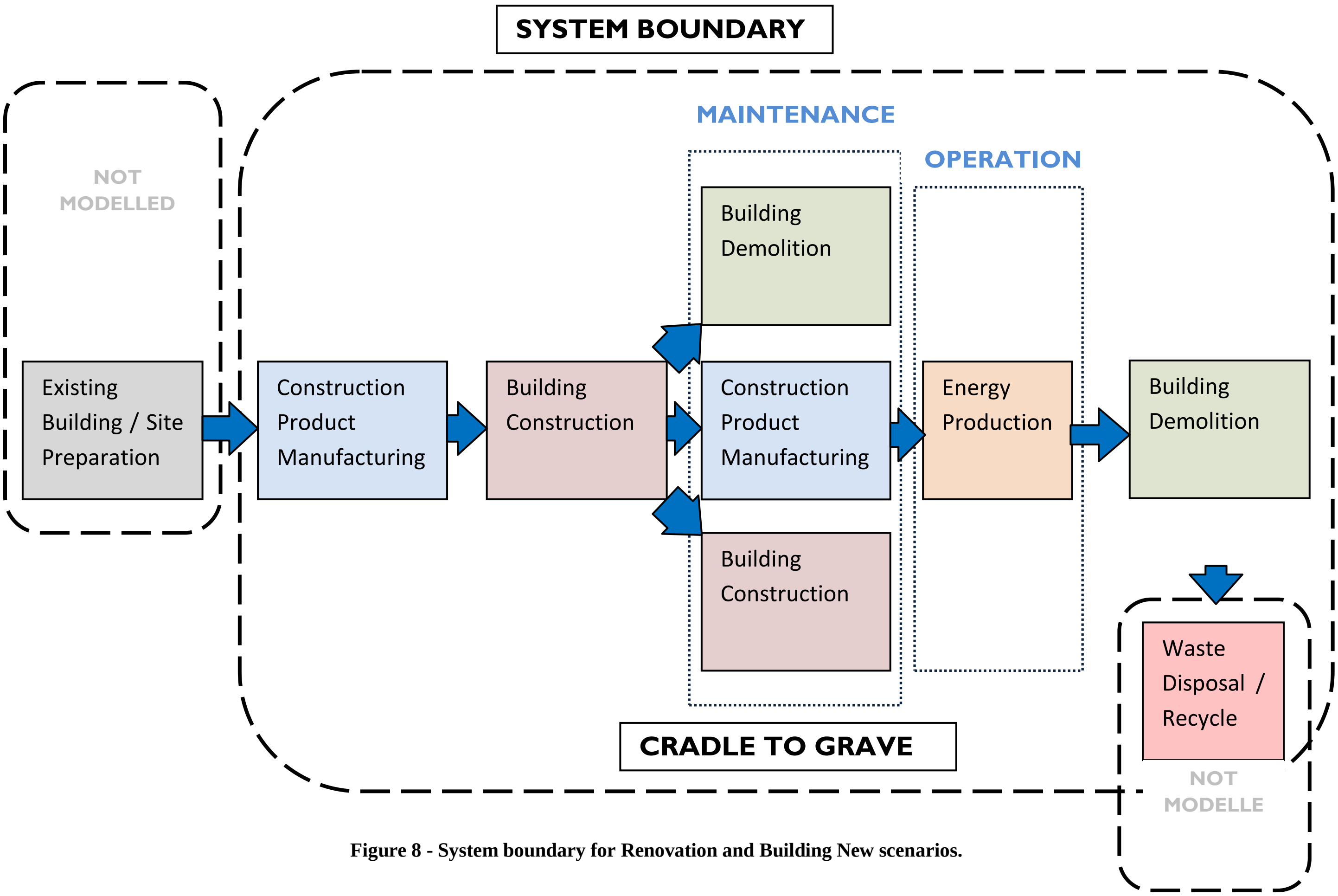


Figure 8 - System boundary for Renovation and Building New scenarios.

The life cycle stages considered in the above system boundary covers "cradle to grave" processes for the CIRS building, however, neither site preparation nor waste disposal unit processes has been modelled as they fall outside the scope of this study. Though, it is interesting to note that CIRS building is almost entirely built from wood and steel products, which have a higher life cycle as well as higher number of cyclic usage – which make them favourable for recycling or reusing processes. The above model captures the sequence of the unit processes from extraction of material to the maintenance & operation of the building product as well as the end of life demolition of the product – this provides an in-depth analysis and out of environmental impacts for the CIRS building.

2.2.3 Functions of the product system

Describes the functions served by the product focused on in the LCA study.

A description of the CIRS building's major functions have been outlined in Article-1: Introduction, of this report.

2.2.4 Functional unit

A performance characteristic of the product system being studied that will be used as a reference unit to normalize the results of the study.

The functional units used in this study to normalize the LCA results for the CIRS Building include:

- per generic post-secondary academic building square foot constructed (e.g. Impact/building gross area)
- per specific post-secondary academic building square foot constructed (e.g. Impact/classroom gross area)
- per generic post-secondary academic building cubic foot constructed (e.g. Impact/building gross volume)
- per post-secondary academic building occupant (e.g. Impact/occupant density)

Further discussion of these functional units and their application are contained in the Impact Assessment sub-section under Functions and Impacts.

2.2.5 Allocation procedures

Describes how the input and output flows of the studied product system (and unit processes within it) are distributed between it and other related product systems.

In this study, the cut-off allocation method was used, which entails that only the impacts directly caused by a product within a given life cycle stage are allocated to that product.

"Specification of the amount of material or energy flow or the level of environmental significance associated with unit processes or product system to be excluded from a study" **ISO 14044**

As CIRS was constructed on virgin site and our LCA study does not include the site preparation as well as waste disposal/recycle unit processes - the end of life phase ends once the waste is transported to their end of life process, and does not include consideration of waste treatment processes or possible subsequent life cycles. Thus the effects of both of those processes are cut off from our modelling and we do not allocate environmental impact to any of those processes. All environmental impacts thus are due to the cradle to grave unit processes in construction, operation & demolition of the CIRS building.

2.2.6 Impact assessment methodology and categories selected

State the methodology used to characterize the LCI results and the impact categories that will address the environmental and other issues of concern.

In a Life Cycle Impact Assessment (LCIA), essentially two methods are followed: problem-oriented methods (mid points) and damage-oriented methods (end points) [http://www.scienceinthebox.com/en_UK/sustainability/lcia_en.html]. For the purpose of our study we used problem oriented (mid-point) methodology through "Tool for the Reduction and Assessment of Chemical and other environmental Impacts (TRACI)", which was developed by the US Environmental Protection Agency (US EPA). In the problem-oriented approaches, flows are classified into environmental themes (impact categories) to which they contribute. Mapped above TRACI framework, methodology by the Athena Institute was also used to characterize weighted raw resource use and fossil fuel consumption.

The impact categories selected and the units used to express them (i.e. category indicators) are listed below.

- Global warming potential – kg CO_2 equivalents
- Acidification potential – H^+ mol equivalents
- Eutrophication potential – kg N equivalents
- Ozone depletion potential – kg CFC^{-11} equivalents

- Photochemical smog potential – kg NOx equivalents
- Human health respiratory effects potential – kg $PM_{2.5}$ equivalents
- Weighted raw resource use – kg
- Fossil fuel consumption – MJ

Short descriptions of each of these impact categories are provided in the Impact Assessment sub-section in Results and Interpretation.

2.2.7 Interpretation to be used

Statement of significant issues, model evaluation results and concluding remarks.

Analysis and discussions of uncertainty, sensitivity, and functional units of this LCA study are contained in the Results and Interpretation section of this report, whereas concluding remarks are contained in the Conclusion.

2.2.8 Assumptions

Explicit statement of all assumptions used to by the modeler to measure, calculate or estimate information in order to complete the study of the product system.

The LCA study for CIRS is carried out using two main workflows i.e. Material take offs from construction drawing and using LCI database from Athena Institute's Impact Estimator; any and all assumptions taken in this LCA study revolve around these two workflows. Assumptions include any and all uncertainty in the information, its unavailability and limitations in the Athena IE software.

The details of the methods used in completing the material take offs on the building drawings are summarized in the Model Development section of this report.

All of the inputs and assumptions associated with interfacing these takeoffs with the Impact Estimator are documented in the Input Document Appendix A and the Assumptions Document Appendix B.

Assumptions regarding the completion of take offs to estimate material use, referenced LCI data and transportation networks have all been developed by the Athena Institute and are built into the Impact Estimator version *4.1.13*. This information is proprietary; however, parts can be accessed through the inner workings report found on the Athena Institute webpage.[1]

2.2.9 Value choices and optional elements

Details the application and use of normalization, grouping, weighting and further data quality analysis used to better understand the LCA study results.

Due to the limited time, resources and scope of the study value choices and optional elements were not included; however, this report does provide sufficient documentation for its audience to carry out these types of analyses.

[1] The Inner Working of the Impact Estimator for Buildings: Transparency Document - http://www.athenasmi.org/tools/impactEstimator/innerWorkings.html

2.2.10 Limitations

Describe the extents to which the results of the modeling carried out on the product system accurately estimate the impacts created by the product system defined by the system boundary of the study.

The following limitations should be considered when interpreting the results of this LCA study.

System Boundary – Any of the impacts created or avoided through the reuse, recycling or waste treatment of the construction or demolition wastes, site treatment, demolition or re-use of any existing structure prior to CIRS construction were outside the scope of this study.

Data Sources and Assumptions – This LCA study used original architectural and structural drawings obtained from Architects "Busby Perkins + Will", structural engineers "Fast + Epp", BIM Modeler "Sheryl Staub French" to develop information on the building assemblies. LCA models and environmental impacts are specific to CIRS only as evident from the Appended documents. Furthermore, the life cycle inventory flows and their characterization reflect averages of industry processes and their impacts for North America. This is due to the fact that those industries engaged in the North American construction market are currently not providing this LCI data. Furthermore, it was not possible to regionalize the impacts of processes and their inventory flows due to time and resource constraints in conducting this study.

2.2.11 Data quality requirements

Qualitative and quantitative description of the sourced data used in the study including its age, geographical and technological coverage, precision, completeness, reproducibility and uncertainty.

The sources of data used in the development of this LCA study include those used to estimate results for the bill of materials, life cycle inventory (LCI) flows and the characterization of LCI flows.

Bill of materials – Architectural, structural drawings and BIM model was obtained from Architects "Busby Perkins + Will", structural engineers "Fast + Epp", BIM Modeler "Sheryl Staub French" to develop information on the building assemblies. We used the 3D BIM model to acquire any missing or ambiguous information in the drawings. The precision of the input data does rely somewhat on the limitations and quantity estimating engine built into the Impact Estimator, as most of the data in auto-generated by Impact Estimator based on the input geometry parameters. However, Impact Estimator inventory can easily be reproduced as all the input data and Assumptions are recorded in documents contained in Appendix A and B in this report.

LCI flows – The Athena LCI Database was the source of LCI data. Assessment and verification of the quality of the data and modeling assumptions used to develop the Athena LCI Database (which is built into the Impact Estimator) was outside the time and resource constraints of this study. However, some of this information can be accessed through the inner workings report found on the Athena Institute webpage[2]. Generally speaking, this database is specific to the current North American context, and thus does create some geographic and temporal limitations on this study. For instance, i) The construction product manufacturing as well as fuel refining and production LCI data is based on North American averages ii) The transportation matrix that estimates distances and modes for construction product

[2] The Inner Working of the Impact Estimator for Buildings: Transparency Document - http://www.athenasmi.org/tools/impactEstimator/innerWorkings.html

transportation as well as construction and demolition wastes is specific to Vancouver, British Columbia iii) The LCI data and modeling parameters in the Impact Estimator were developed by the Athena Institute to reflect current circumstances and technologies.

Characterization factors – Documentation of the US EPA TRACI impact assessment method can be found on the US EPA website[3], and documentation for the development of the weighted resource use impact category can be found on the Athena Institute webpage[4]. Generally speaking, this method characterized LCI flows to reflect their potential to cause damage on average in North America. Qualitative discussion of the uncertainties present in the impact assessment results are contained in this report in the Impact Assessment sub-section of Results and Interpretation.

2.2.12 Type of critical review

A review of the methods, data, interpretations, transparency, and consistency of the LCA study.

This report is developed as contribution to knowledge, not for comparative assertions; however, enough data is made available that any such comparison can be carried out given that the user is well aware of the limitations of the scope and model of this study. It is advised that the authors be contacted if one wishes to include or use these results in future circumstances outside those outlined in the intended application for this study.

2.2.13 Type and format of the report required for the study

Statement of the type and format followed by the report.

This report followed the final report outline provided by Rob Sianchuk - the instructor of the LCA course this project was carried out under in the UBC Civil Engineering department.

3. Goal and Scope

3.1 Structure and Envelope

3.1.1 Motivation

Creating a 'Bill of Materials' from construction or as built drawings can be both time consuming and error prone. Major portion of time is consumed generating life cycle inventory and inputs for the Athena Impact Estimator for Buildings. Specifically, dissecting architectural and structural drawings into linear and area conditions typically requires the use of takeoff software such as 'On ScreenTakeoff' or 'Autodesk Quantity Takeoff'. With the advent of Building Information Modeling (BIM) and it's progressive use in 3D visualization and data acquisition, a huge potential exists in automated generation of 'Bill of Materials' from building models. Software like Autodesk Revit or Google Sketup which is free to use, further elaborates and highlights the usability of such software to automate the otherwise cumbersome process of quantity take off. In using BIM and auxiliary software, it was the authors' intentions to: 1) create an accurate 'Bill of Materials' for roof and floor assemblies at the Centre for Interactive Research on Sustainability, 2) test the suitability of an easily accessible and automated

[3] US EPA TRACI documentation - http://www.epa.gov/nrmrl/std/traci/traci.html

[4] Weighted resource use impact category development - http://www.athenasmi.org/wp-content/uploads/2011/10/16_ECC_Impacts_of_Resource_Extraction.pdf

workflow to generate the 'Bill of Materials', and 3) Create a model that could visually represent the 'Bill of Materials'.

3.1.2 Material Take off

3.1.2.1 Software

Google Sketch up - The software used to generate a 'Bill of Materials' for the floor and roof assemblies was Google SketchUp. Google SketchUp is a widely used 3D modeling software, with free and professional version. The software has been used in a variety of fields and allows users to rapidly design validate and visualize 3D environments. Like other takeoff programs, SketchUp allows the import of jpeg, pdf and autocad files upon with area and linear conditions can be drawn (Figure 1). In order to facilitate the automated extraction of area conditions an extension was written in the ruby programming environment. The ruby programming environment allows the extension of modeling capability in SketchUp, in this case the extraction of geometric area totals for each material in a model. This is done by determining an appropriate naming nomenclature for a list of materials and assigning them to their respective geometric definitions. Examples of other 'Bill of Material' ruby extensions can be found here:
http://forums.sketchucation.com/viewtopic.php?p=250026

Other Software - Further, other software like "On-Screen Take-Off", "Autodesk Quantity Take-Off", "Autodesk Revit Architecture" were used to develop a complete life cycle inventory for the concerned building. All the outputs of the quantity take off; either from Autodesk QTO, Sketch up or Onscreen Take-off were recorded in logical nomenclature for better referencing and input to Athena IE. All the measured parameters as well as associated data & assumptions for Athena IE are presented in "IE Input document", See Appendix B.

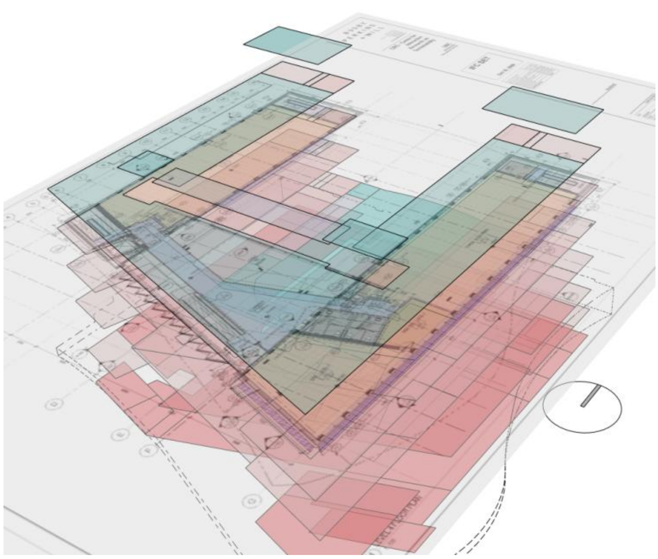


Figure 8 - Sketch up model for floors & roof

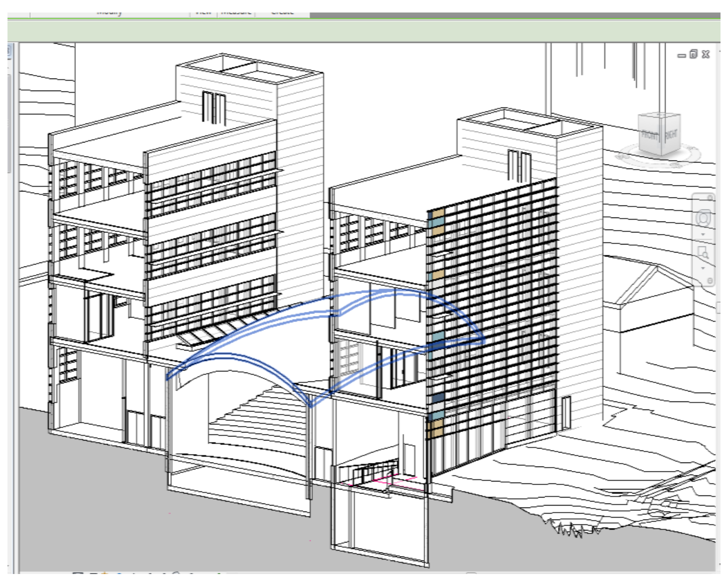


Figure 9 - Revit Model for stairs & beams

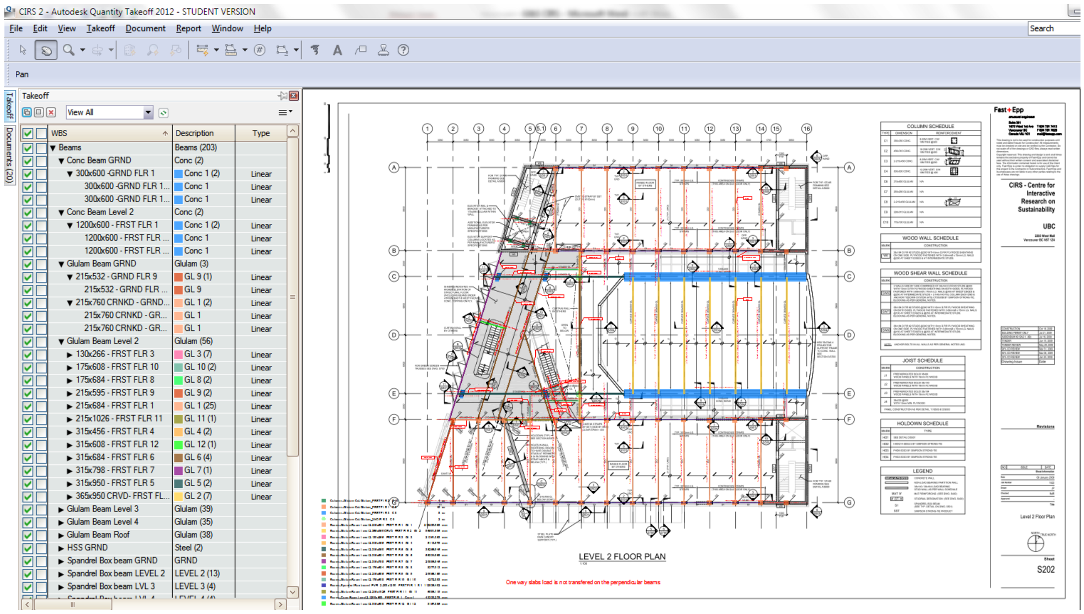


Figure 10 - Autodesk Quantity Takeoff for Beams & Columns

All drawings were provided in electronic format and were compatible with above mentioned software, however, Sketch up model was designed by one of the authors and was customized for quantity take off for this study. Although, there were not much challenges in quantity take off from the drawings as the information provided was quite comprehensive, however some of the components specially stairs were not explicitly annotated in the drawings as well as BIM model. Several assumptions and manual calculations were carried out to quantify the stairs as accurately as possible. Following sections would discuss how building components (products) were quantified and what were the assumptions and limitations in the calculations.

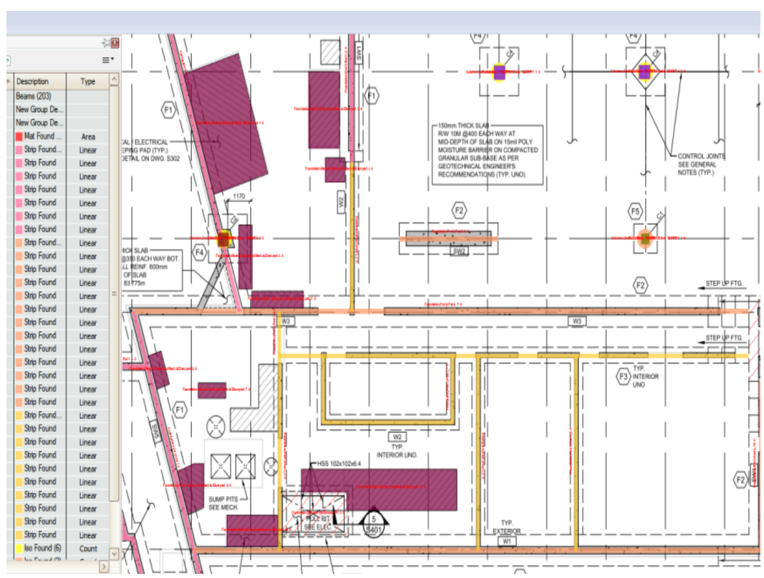


Figure 11- Autodesk QTO for foundations

3.1.2.2 Foundations:

Foundation system in CIRS consist mainly of concrete wall foundation (Strip foundation) under all the shear walls and basement walls, isolated footing for single columns and mat foundations under elevator pits. Quantities were taken off from structural drawings (Fast + Epp) S200 & S 201 using Autodesk QTO. Input parameters for Athena IE like concrete strength, fly-ash percentage etc., were taken from structural general notes drawing S100 & S101. Concrete strength for foundations was reduced from 4350 psi to 4000 psi due to the limitation in

Athena IE's query module for strengths above 200psi. Foundations were measured using linear condition as Athena IE requires only dimensional inputs for foundation estimation.

3.1.2.3 Floors:

IFC Drawings with floor constructions were scaled, oriented and traced in Google SketchUp. A material library, along with appropriate naming conventions was developed and associated with the SketchUp floor components (Figure 12). Area conditions were then linked to appropriate material types for each floor and exported through aforementioned ruby plugin. Floor widths were determined by dividing the total floor area of each condition by the span of that condition. Where needed IFC drawings where verified on-site, through the BIM and as-built photos. Wherever appropriate, floor concrete strength, concrete flyash content, and live loads were taken from the Architectural and Structural Schedules (See Inputs). Furthermore, several flooring components were excluded in the model due to modeling limitations and uncertainty. The components not included were, carpet, epoxy sealants, and hydronic piping in concrete slabs.

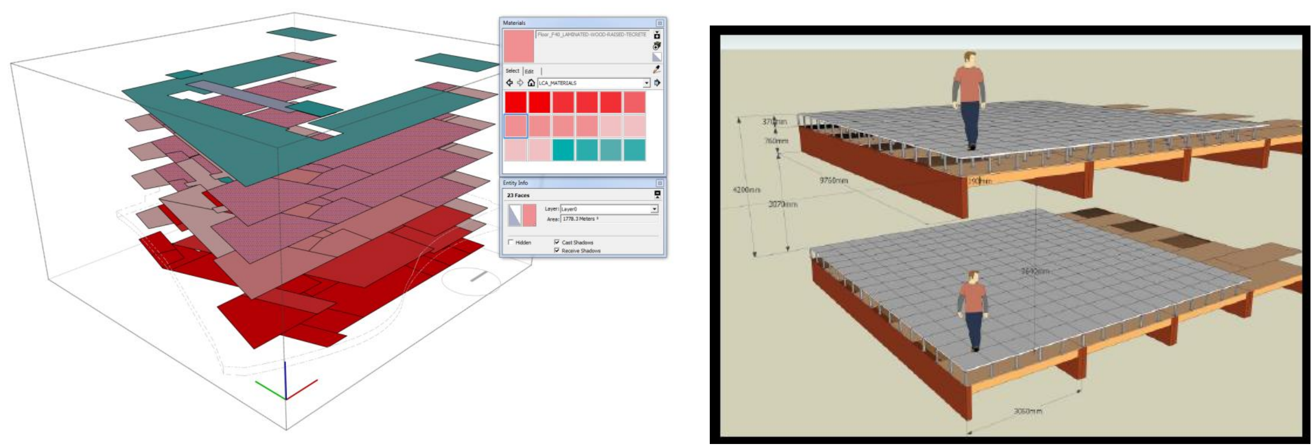
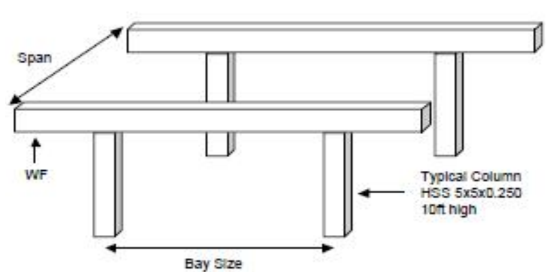


Figure 12 - Google Sketch up Floor system & Flooring system

3.1.2.5 Columns & Beams:



Athena Impact Estimator has an internal database for calculating beam and column dimensions through information of number of columns, supported span, bay size etc. This peculiar way of estimating the material quantities for beams and columns provided quite a lot of challenge for a complicated geometric building like CIRS. Athena also requires presence of column supports in order to calculate beams; this also posed difficulties as most of the intermediate beams in CIRS are supported on other primary beams. The data from secondary or tertiary beams therefore had to be presented in extra base material.

Also both wood and concrete is used as material for beams and columns and various locations, calculations were made separately for both of the materials. Also Athena does not support concrete beams which also posed quite a hassle as some of the larger primary beams in CIRS are concrete beams over Reinforced shear walls.

Athena also does not support bay size larger than 12.2m which also was a big problem in data input, as most of the primary beams in CIRS are of 15m length. All those beams were either calculated through extra base material input or broken down into smaller compatible spans where possible.

*“**Bay size**: bay size (main beam span) that most accurately reflects your design intentions. The bay size is is constrained to be between 3.05 m and 12.2 m for all live loads and beam types*” Athena 4.1.1414 Manual

Columns and beams were calculated using Autodesk QTO software, using numeric condition for Columns and linear condition for beams. As a large number of different wooden beams were used in CIRS along the different floors naming convention was so chosen as to depict a logical meaning of the annotation e.g. 215 x 532 – GRND – GL 9, where as the first numeric were sectional size of the beam, GRND is the location of the beam on ground floor, and GL 9 means Glulam 9th type on that floor. The same convention was used for columns as well.

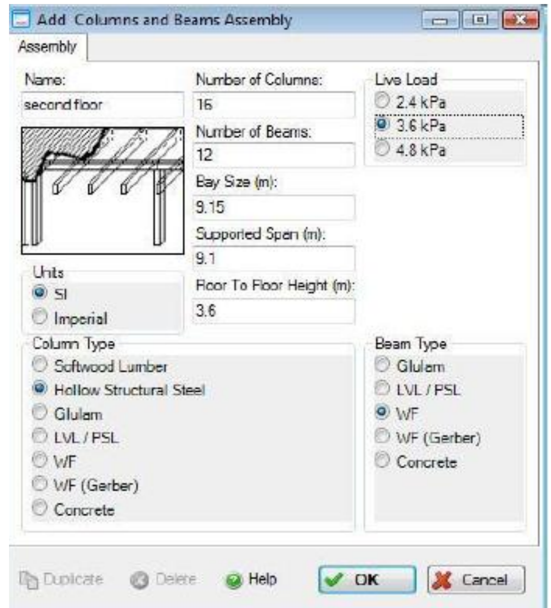


Figure 13 - Athena query form for beams

As all the floor to floor stairs in CIRS are made of wood – Glulam wooden stringers, stairs were calculated as beams and taken in extra base material as Glulam wood.

3.1.2.5 Roofs:

IFC Drawings with roof constructions were scaled, oriented and traced in Google SketchUp. A material library, along with appropriate naming conventions was developed and associated with the SketchUp roof components. Area conditions were then linked to appropriate material types for each roof and exported through the aforementioned ruby plugin. Roof widths were determined by dividing the total floor area of each condition by the span of that condition. Where needed IFC drawings where verified on-site, through the BIM and as-built photos. Wherever appropriate, live loads were taken from the Architectural and Structural Schedules (See Inputs). Furthermore, several roof components were excluded in the model due to modeling limitations and uncertainty. The components not included were, plant and growing medium, green roof root barrier and protection board.

Extra Basic Materials - As there were many unconventional floor and roof constructions found in CIRS, several materials needed to be input into Athena Impact Estimator for Buildings through the ‘Extra Basic Materials’. This included laminated-wood flooring, raised-floor tec-crete, raised-floor pedestals, and concrete topping. Volumes for laminated-wood flooring, raised-floor tec-crete, and concrete topping were determined through area conditions and measured depth on IFC drawings. An estimate of weight for the raised-floor pedestals was determined by: 1) estimating the volume of each pedestal, .0006m3, 2) determining the count of each pedestal, count = ((number of tec-crete panels) 1/2 + 2)2 = 4803, and 3) determining the weight by combing outputs from 1 and 2 with the density of steel (8000 kgm-3).

3.1.3 Use phase:

The unique thing about CIRS is that it was designed to be a net-zero energy building and is also part of the “living building challenge”, therefore it has a high mandate for performance measurement and monitoring. During the design phase of the CIRS model, several energy models were created to reduce and optimize the energy consumption of the building keeping occupant comfort unchanged and of foremost important throughout the process. In addition the whole building has been fitted with sensors to record different aspects of building performance as well as record occupant interaction & behavior. This intense exercise brought out quality data for energy consumption of the building as well as means to monitor and control energy usage throughout its life cycle.

For the purpose of this study, we did not model or measured any energy utilization at the building. However, we intend to relate and support LCA study results with design and LEED submitted energy usage data, so as to equip and encourage further manipulation and analysis of this data.

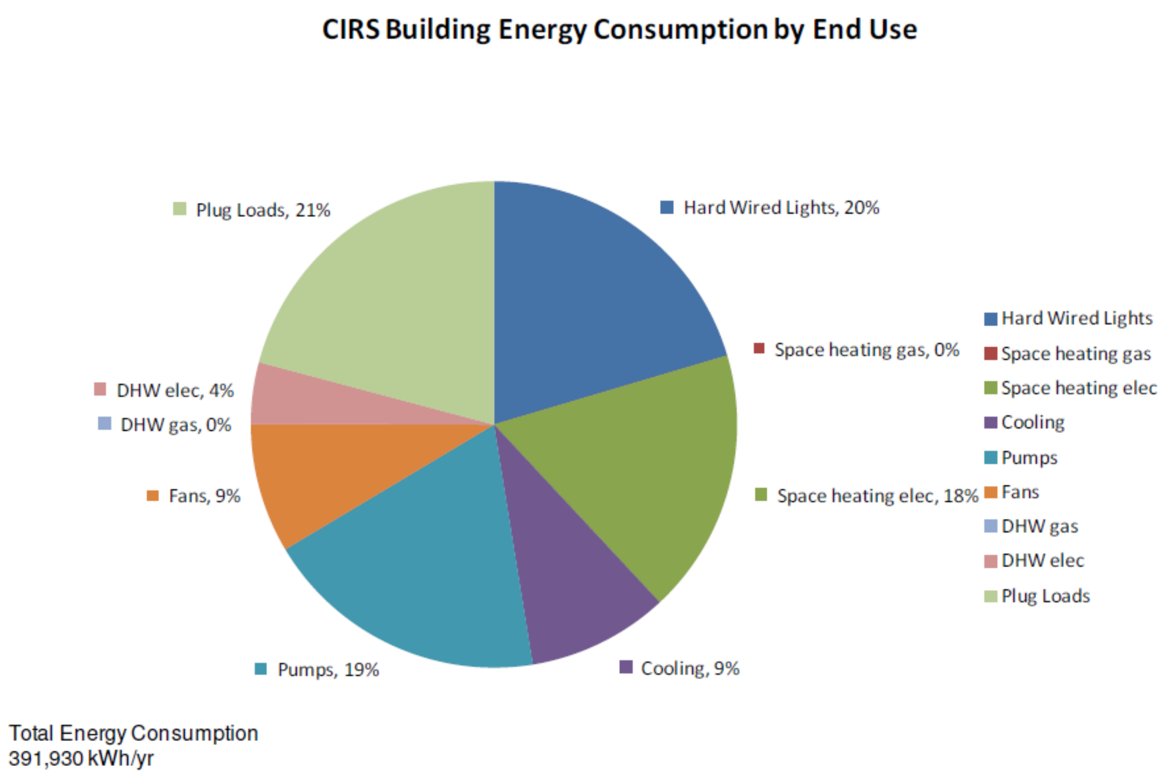
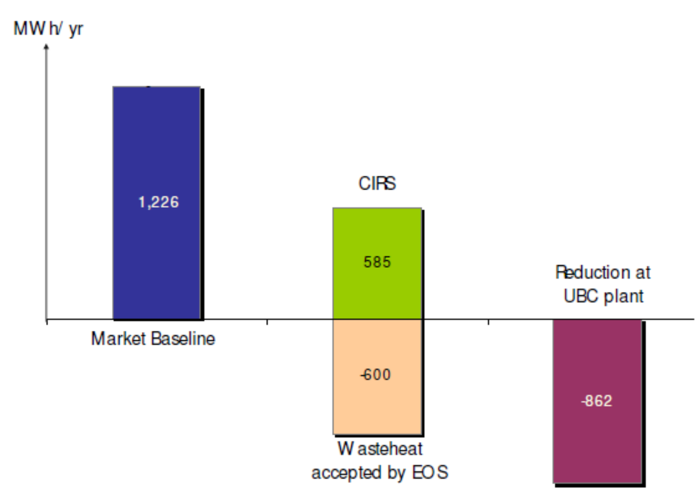


Figure 14 - CIRS building Annual energy consumption by End use – Courtesy Stantec Consulting Excerpt from UBC - Centre for Interactive Research on Sustainability (CIRS) LEED report

The above results are excerpted from Statecs energy model report for LEED compliance and are presented for reference purposes only. The energy model was created in eQUEST 3.61. The above figures do not represent the actual usage of the building but projects what the building would be using under the design conditions. Actual energy usage will differ from these calculations due to a number of variables including but not limited to: variations in occupancy and building operations schedules; energy use for equipment not included in the simulations



or not covered by the applicable energy code (process energy); differences between actual weather and the typical meteorological year represented in the climate data file; and changes in energy costs.

CIRS has achieved 68% less energy utilization from the market baseline of similar size, similar use buildings. Also it has contributed towards positive heat energy production for the adjacent Earth and Ocean Sciences building.

4. Results and Interpretation

4.1 Inventory Analysis

4.1.1 Bill of Materials

The bill of materials was generated from the output of Athena Impact Estimator inventory. The quantities were not taken from the quantity take off documents, as they were measures of the assemblies of building products not the constituent materials. Athena IE breaks down all the building assemblies into their respective quantities through complex back ground calculation algorithms and data manipulation from its data inventory. Bill of materials for CIRS as retrieved from Athena IE is shown below:

CIRS - Bill of Materials		**Assembly Group**					
Construction Material	**Units (use Metric !)**	**Foundation**	**Walls**	**Floors**	**Columns & Beams**	**Roof**	**Building Total**
1/2" Regular Gypsum Board	m2		531.51	98.24			629.75
1/2" Moisture Resistant Gypsum Board	m2		348.04				348.04
5/8" Regular Gypsum Board	m2		7016.73				7016.73
3 mil Polyethylene	m2		44.12				44.12
6 mil Polyethylene	m2	2291.80	3517.50	56.17		1552.72	7418.18
Concrete 30 MPa (flyash 25%)	m3	306.60		411.53	1.80		719.93
Concrete 30 MPa (flyash 35%)	m3	89.79					89.79
Concrete 30 MPa (flyash av)	m3		1034.48		137.39		1171.87
Concrete Blocks	Blocks			86.21			86.21
Galvanized Sheet	Tonnes		3.78	0.03		0.02	3.83
Hollow Structural Steel	Tonnes			22.85	98.32		121.17
Joint Compound	Tonnes			0.10			0.10
Large Dimension Softwood Lumber, Green	m3			359.73		135.62	495.35
Large Dimension Softwood Lumber, kiln-dried	m3			3.43		1.33	4.77
Nails	Tonnes		1.18	0.02		0.01	1.21
Paper Tape	Tonnes		0.09	0.00			0.09
Rebar, Rod, Light Sections	Tonnes	1.10	31.39	23.31	65.03		120.83
Softwood Plywood	m2 (9mm)		3654.84	187.54		57.56	3899.95
GluLam Sections	m3				464.66		464.66
Aluminum	Tonnes		36.43				36.43
Batt. Fiberglass	m2 (25mm)		10099.98				10099.98
Batt. Rockwool	m2 (25mm)		8151.98				8151.98
Blown Cellulose	m2 (25mm)		576.06			85.14	661.20

Cold Rolled Sheet	Tonnes		0.21				0.21
Concrete Brick	m2		1079.22				1079.22
EPDM membrane (black, 60 mil)	kg		2305.67				2305.67
Expanded Polystyrene	m2 (25mm)		6541.07			750.11	7291.18
Foam Polyisocyanurate	m2 (25mm)		658.07				658.07
Galvanized Studs	Tonnes		6.63				6.63
Glazing Panel	Tonnes		253.80				253.80
Joint Compound	Tonnes		7.92				7.92
Low E Tin Argon Filled Glazing	m2		723.95				723.95
MDI resin	kg		44.19				44.19
Mortar	m3		20.04				20.04
Oriented Strand Board	m2 (9mm)		237.05				237.05
Screws Nuts & Bolts	Tonnes		1.73				1.73
Small Dimension Softwood Lumber, kiln-dried	m3		60.99			0.07	61.06
Solvent Based Alkyd Paint	L		10.61				10.61
Solvent Based Varnish	L		297.36				297.36
Water Based Latex Paint	L		42.73				42.73
Ballast (aggregate stone)	kg					7798.03	7798.03
PVC membrane	kg					14682.74	14682.74
Welded Wire Mesh / Ladder Wire	Tonnes	2.64					2.64

Table 1 – Bill of Materials

Top most significant materials used in CIRS can be easily interpolated from the above table, and are given as:

I. PVC membrane
II. Batt Fiberglass
III. Ballast (aggregate stone)
IV. 6 mil Polyethylene
V. Expanded Polystyrene

PVC membrane: The large amount of PVC membrane in the BoM, comes solely from insulation of the roof which also includes the green roof of CIRS building, as shown in Appendix A. The wooden roof is insulated by a 60mm thick PVC membrane as a roofing envelope. There was no information provided as to the specification of the PVC membrane in the architectural & structural drawings. Even the roof description just held the information of the presence of the PVC layer and no drawing is shown to quantify the membrane from. Therefore, the area of the membrane was calculated based on the area of the Roof elements.

Another assumption needed to me made in part for the input of PVC membrane quantity into Athena IE query, there was no category of PVC insulation in Roof assembly. Therefore, this material was added into Athena's inventory as an extra based material under "roofing". However, this input parameter required "Kg" input for the PVC membrane material, and no information was available as to the density or weight of the membrane used in the building. A weight of 181kg per 92.9m^2 was used to calculate Athena compatible input parameter. This figure was acquired from a popular vendor of PVC membranes Johns Manville:

JM Corporate Headquarters

717 17th Street
Denver, Colorado 80202
Phone: 303.978.2000

http://www.specjm.com/commercial/roofing/pvcsingle.asp

60 mil	x	x	x	x	x						6.5' x 100' (2 m x 30.5 m)	650 ft² (60.4 m²)	260 lb (118 kg)
											3.25' x 100' (1 m x 30.5 m)	325 ft² (30.2 m²)	130 lb (58.9 kg)
											10' x 100' (3.1 m x 30.5 m)	1,000 ft² (92.9 m²)	400 lb (181.4 kg)
											5' x 100' (1.5 m x 30.5 m)	500 ft² (46.5 m²)	200 lb (90.7 kg)

Figure 15 - weight assumed for PVC calculation

Fiberglass batt: Most of the fiberglass batt is used as acoustic insulation in the dry wall assemblies throughout the building enclave. This insulation ranges from 64mm to 152 mm as per the wall assembly shown in wall assembly drawing A-011. Although there was comprehensive information on wall assemblies, the source of ambiguity would be Athena's database itself. Athena IE does not require wall thicknesses as an input parameter and calculates them automatically as per the given height and length of the wall. This might prove to be quite erroneous, as it is uncertain what thickness of wall Athena determines and would it match the wall thickness given in the drawings. This would ultimately effect the actual calculations of the insulation and can lead to lower or higher estimates.

Ballast (aggregate): The third highest material quantity also comes from roof structure. However, this quantity is also based on the internal calculations by the Athena IE and cannot be ascertained through drawings. The roof structure of CIRS is laminated wood with vapour barrier, extruded polystyrene and PVC membrane layer, a small portion of the roof slab 83m^2 has concrete tile as roof envelope. Other than this small amount of concrete tiles, roof system of CIRs is made mostly of wood and there is no detail of ballast to be confirmed from the drawings. The same uncertainty remains with the Athena calculated ballast at roof as was with acoustic insulation in walls, the parameters or mathematic equations are unknown and could lead to exaggerated quantity estimates.

6 mil Polyethylene: Polyethylene is used as a vapor barrier in almost all the building components, but the highest quantity comes from the walls. 6 mil Polyethylene is a given parameter in Athena LCI inventory query forms and Athena calculates the volume of the vapor barrier based on wall area. The chance of area in this regards is minimum as all the input data is manually done by the software operator and volume can be calculated by simple arithmetic calculations.

Expanded Polystyrene: The insulation was found in roof and wall assemblies and varies from 150mm (roof) to 100mm (walls). Athena allow for variable thicknesses of the insulation and calculates volume from the given thickness parameter and wall area from the length and area parameters of the wall. The chance of area in this regards is minimum as all the input data is manually done by the software operator and volume can be calculated by simple arithmetic calculations.

Although, BIM model for the CIRS building is available, the model itself is not rich enough with appropriate information to calculate the Bill of Materials as extensive as calculated by Athena Impact Estimator.

4.1.2 Energy Use:

As already mentioned in Article 3.1.3 Use Phase, for the purpose of this study no formal calculations were made to measure the energy usage of the building neither by modeling the utilization nor by measuring meter readings from outside BC Hydro meters.

	CIRS alone energy use	CIRS + preheat EOS	Waste heat accepted by EOS
	kWh	kWh	ekWh
Lighting	87951	87951	
Heating - Elec	76023	249759	
Heating - Gas	0	0	
Cooling	40385	40385	
Pumps	81696	101724	
Fans	37161	62012	
DHW - Gas	0	0	
DHW - Elec	17584	17584	
Plug Loads	89856	89856	
Renewables	-38727	-38727	
Total	**391929**	**610544**	**622063**

Table 2 – Energy Utility Summary

As from the above table, CIRS is designed to take all its power requirements from BC Hydro Grid and does not use gas or other fuel resources for energy generation. Through its unique heat exchange system CIRS is actually capable of providing heat energy to its adjacent building and contributes to minimize its heat use signature.

4.1.3 Impact Assessment:

As described earlier, Athena Impact Estimator uses TRACI as an Impact assessment methodology to calculate the environmental impacts. TRACI is a problem oriented (mid-point) Impact assessment tool which covers assessment categories as Article 2.2.6. The following table describes the environmental impacts as per life cycle stages i.e. construction manufacturing etc and assembly groups i.e. foundations, walls etc:

Life Cycle Stage	Process	Global Warming Potential	Assembly Group					Building Total
			Foundation	Walls	Floors	Columns & Beams	Roof	
Manufacturing	Total	kg CO2 eq	100699.43	770669.08	156892.82	277791.15	13001.72	1319054.19
Construction	Total	kg CO2 eq	10327.19	46759.03	11838.45	6076.02	1693.68	76694.36
Maintenance	Total	kg CO2 eq	0.00	326656.10	0.00	0.00	31973.56	358629.66
End-of-Life	Total	kg CO2 eq	5240.71	19433.39	12825.57	18408.63	2545.61	58453.91

Table 3 – Global Warming Potential

Life Cycle Stage	Process	Acidification Potential	Assembly Group					Building Total
			Foundation	Walls	Floors	Columns & Beams	Roof	
Manufacturing	Total	moles of H+ eq	35127.26	412496.43	53451.86	99131.38	7798.54	608005.47
Construction	Total	moles of H+ eq	4187.13	18726.21	4843.84	3647.38	540.02	31944.59
Maintenance	Total	moles of H+ eq	0.00	173589.26	0.00	0.00	23973.45	197562.71
End-of-Life	Total	moles of H+ eq	912.17	3481.13	1488.08	1390.37	190.42	7462.16

Table 4 – Acidification Potential

Life Cycle Stage	Process	Fossil Fuel Use	Assembly Group					Building Total
			Foundation	Walls	Floors	Columns & Beams	Roof	
Manufacturing	Total	MJ	729640.17	6706949.83	1827890.57	5279912.64	319848.33	14864241.55
Construction	Total	MJ	151102.55	647519.92	183701.69	151024.19	22735.43	1156083.79
Maintenance	Total	MJ	0.00	1399065.43	0.00	0.00	878536.83	2277602.27
End-of-Life	Total	MJ	75653.38	279783.28	190817.43	279561.74	38672.87	864488.70

Table 5 – Fossil Fuel Use

Life Cycle Stage	Process	Weighted Resource Use	Assembly Group					Building Total
			Foundation	Walls	Floors	Columns & Beams	Roof	
Manufacturing	Total	ecologically weighted kg	1023900.74	3663336.32	1615360.84	1552138.83	172142.40	8026879.13
Construction	Total	ecologically weighted kg	3527.33	15162.67	4290.83	3532.93	535.65	27049.40
Maintenance	Total	ecologically weighted kg	0.00	387329.70	0.00	0.00	30907.63	418237.32
End-of-Life	Total	ecologically weighted kg	1781.87	6589.84	4493.68	6582.95	910.64	20358.98

Table 6 – Weighted Resource Use

From the above Table 5 and Table 6, it is evident that during the manufacturing and construction phase, primary energy consumption and weighted resource use is very significant. This is because primary energy includes all energy used to transform and transport raw materials into products, as well as the indirect energy required for processing and transporting energy, which is dominant during the manufacturing and construction stages. Resource use is associated with resource extraction, which is also predominant in the manufacturing stage, however a significant portion of the resource use is also seen in the maintenance & operations part as that involves input of resources in the form of repairs, maintenance & renovation of building components. As for the HH respiratory effects potential, eutrophication potential, ozone depletion potential, and smog potential categories, the total effects on the CIRS are not as extensive during the manufacturing and design phases. Their impacts may become more significant during the operation, maintenance, and demolition stages.

4.1.4 Uncertainty:

Many uncertainties are pertained in the process of carrying out LCA study of CIRS building due to the inherent complexity of the building product as well as study phases and tools used. Such uncertainties should be made explicit and transparent during the study to make the audience aware of any deficiency in the dataset or limitations in the tools used for the assessment process, giving a fair outlook towards the goal of the study. As described in above Article – 2.2.8, limitations and assumptions made during this study are made explicit in the input and assumption document, see Appendix A.

The objective of Impact Assessment is to present the environmental impacts of the system in a form that meets the purpose of the study and can be understood by users of the results. Specific use of assessment method is determined by appropriate study of goal and scope. Use of inappropriate assessment method "mid-point" for a study focused on damage of environmental impacts on human or ecosystem would create uncertain and false results.

According to ISO 14040, the impact assessment phase of LCA addresses only the environmental issues specified in the goal and scope and thus is not a complete assessment of all potential issues (Canadian Standards Association, 2006).

One major concern is that uncertainties (model, scenario and parameter) may be extremely high beyond well-characterized midpoints, resulting in a misleading sense of accuracy and improvement over the midpoint indicators when presented to weighting panels and decision makers. (Midpoints versus Endpoints: the Sacrifices and Benefits, Bare C Jane et al). In this study fossil fuel impact category encompasses the total energy usage during different life cycle phases of the building however it does not differentiate between the different energy sources used for different work processes. This produces a high uncertainty in maintenance & operation life phase for Green buildings and especially in case of CIRS which is a self sustained net-zero energy building. In Vancouver the major grid energy comes from Hydro energy and does not utilize any fossil fuel usage to produce primary energy. This in one way distort the results available in Athena IE, as construction and manufacturing processes based in BC, does not contribute to such higher fossil fuel usage as indicated by the impact assessment.

There are always data gaps and unavailability of data sets in an LCA study, rendering almost all the studies incomplete and with limited amount of uncertainty inherent in them. In this study many of the material details were made explicit neither in drawings nor in 3D BIM model, creating uncertainty about the actual material used in the construction process and the input parameter chosen to be substituted in the LCI database. For example, there are no details of wood used for the treads of all the stairs in CIRS buildings in the drawings and it produces an obvious uncertainty between what is actually used in the building and what is appropriately assumed material to be take in the LCA model inventory.

Data uncertainty within the impact assessment phase arises from the characterization of emissions, due to the dynamic nature of the various impacts. The impact categories can be heavily influenced by different factors such as unknown lifetimes of substances, time of year, location, temperature, industrial activity, etc. In addition, the travel potential of various emissions is not accounted for during the assessment, and could possibly have a significant effect on the results.

There is an inherent uncertainty in available data from sources (factories) which are geographically too apart from each other. Geographic differences have a significant effect on the reliability and validity of the life cycle assessment of a product, given to different ecological and behavioral conditions attributed to different regions. As Athena Impact Estimator LCIA engine works in the background with implicit database, it is hard put to judge the geographical impact of material sources taken in the IE and that of used in the construction of the CIRS building. Athena LCI takes an average estimate of the impacts across a range of manufacturing facilities across an even wider range of geographic spread; this underscores impacts due to environmental sensitivity of different regions and propagation of those effects to the construction site.

The Climate change models in an LCA study takes into account for future emission scenarios to determine the effects of releases currently taking place. A certain time frame is required to quantify the impacts and carry out a substantial assessment process. Uncertainty in effect of climate over the time frame would have inaccurate and uncertain environmental impact calculations. The impact assessment performed on this study is not interpreted over time, nor does it account for the effects of varying climate and temperature. These temporal factors could be highly influential on the different impact categories.

4.1.5 Sensitivity Analysis:

"The key purpose of sensitivity analysis is to identify and focus on key data and assumptions that have most influence on a result. It can be used to simplify data collection and analysis without compromising the robustness of a result or to identify crucial data that must be thoroughly investigated." (*Annex 31, Energy related environmental Impact of buildings, 2001*)

For the purpose of this study, sensitivity analysis was carried out for the top 5 substantial and impact prone materials observed from the life cycle inventory. 1 – PVC Membrane, 2 –Fibreglass Batt (Acoustic Insulation), 3 – Ballast (Aggregate), 4 – Polystyrene (6 mil), 5 – Expanded Polystyrene.

Effect of a 10% increment of the above material would be studied as a sensitivity change on life cycle stages as well as the impact categories of the building LCA. Sensitivity analysis of influential materials equip the user with a powerful decision making & verification tool to observe and compare the effects on the overall performance of a building thus selecting the most optimal materials for an assembly. As per ISO 14044: Sensitivity analysis enables assessment of the consequences on the LCIA results of different value-choices and highlighting those in terms of impact category variations.

4.1.5.1 Primary Energy Use:

In this study Primary Energy is the total energy used for making and moving the structural and envelope materials, on-site construction, maintenance and repair or replacement of relevant materials (e.g., roofing) over the building life, demolition, and transportation to landfill or waste plant. This includes inherent energy contained in raw materials as well as indirect energy use associated with processing, converting, and delivering energy. Athena IE also converts the operational energy of a product and represents it in the form of primary energy use. Primary Energy Use is represented in mega Joule (MJ).

The change in the primary energy use is showcased in Fig 13, is due to 10% Increment in the above mentioned 5 materials. It is observed that PVC membrane yields the largest of effects on the primary energy usage among other materials. This significant peak is due to the fact that PVC roofing membranes require quite a lot of manufacturing and construction energy compared to the manufacturing and construction energy of the other 4 materials as seen from Athena LCI for ICI roofing systems – on site construction, 2001.

ENERGY INPUTS		
On site electricity input	KWH/square	0.165+.04
On site propane use	kg/square	0
On site diesel use	l/square	0.872

Athena Sustainable Materials Institute, "Life Cycle inventory of ICI roofing systems: Onsite construction effects", Ottawa 2001

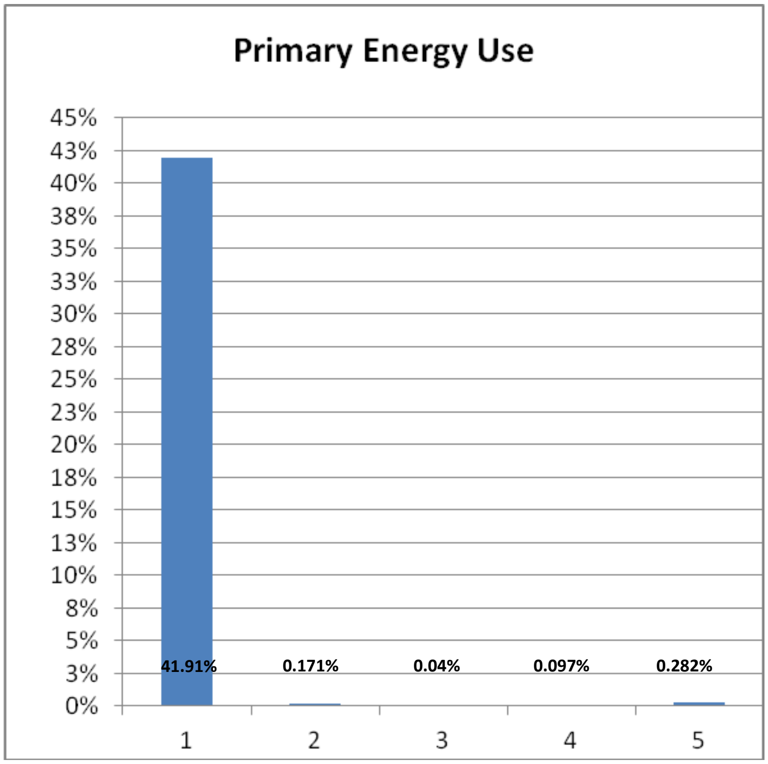
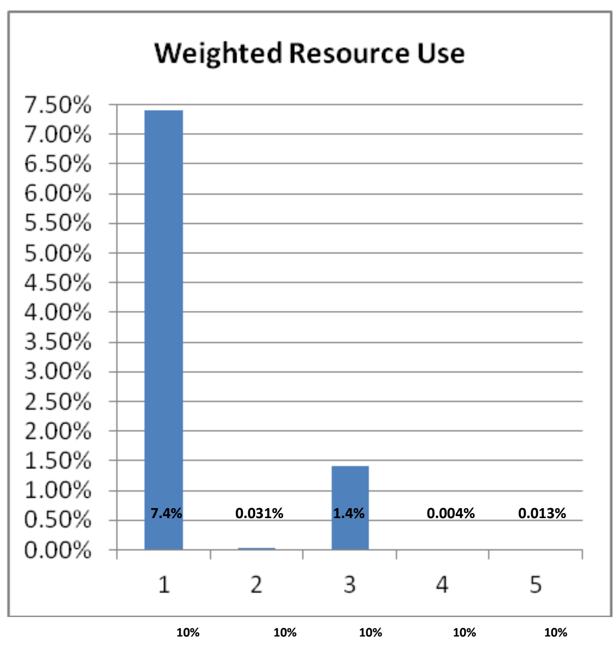


Figure 16 - Sensitivity analysis for Primary Energy Use

The other materials do not contribute towards change in Primary energy use to the extent of PVC membrane as most of the materials, e.g. fiberglass, ballast etc are usually byproducts of some other manufacturing processes and do not have significant construction energy usage as well.

4.1.5.2 Weighted Resource Use:

Measure of all the natural resources that took to get or create the building materials is represented in Resource usage. This includes all the materials in the end product as well as everything required to install and manufacture the product, like formwork and false work, used in cast-in-place concrete. However, environmental impacts of extracting raw materials from different sources are not the same; normalization is required to easily compare all of these resources. An ecologically weighted system is used to compare construction products. The total is expressed as an ecologically weighted mass of raw material consumption in Kilograms.



In our study, as evident from the primary energy use "PVC roofing membrane" shows the highest peak of resource usage which in retrospect explain higher energy usage as well.

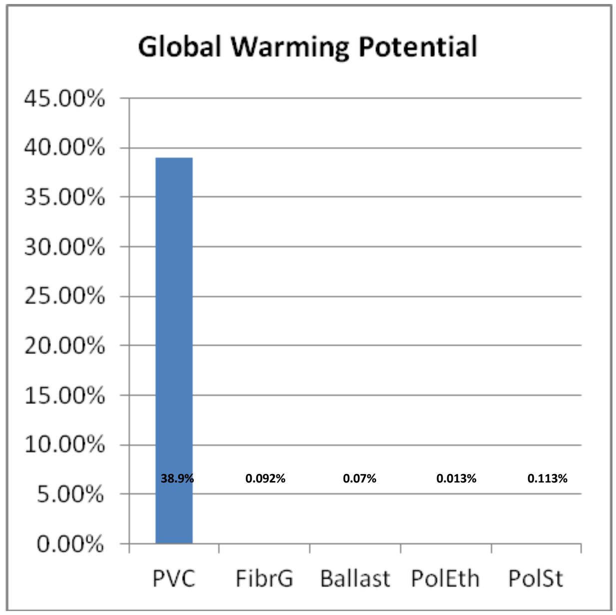
4.1.5.3 Global Warming Potential:

Global warming potential is the measured in terms of greenhouse gas ability to trap heat in the atmosphere relative to carbon dioxide (CO_2) over specified time duration. This is measured in equivalence of CO_2 – means amount of emission producing the same global warming effect as a certain mass of CO_2.

Studies[5] have shown that the life cycle of PVC largely contributes to negative environmental impacts, such as green house gas emission, global warming, energy consumption and waste construction.

Burden	Rigid PVC	Flexible PVC
CO_2	1.846	1.152
Dust	3.70	2.31
SO_2	12.34	7.71
NO_x	15.19	9.48
HCl	0.22	0.14

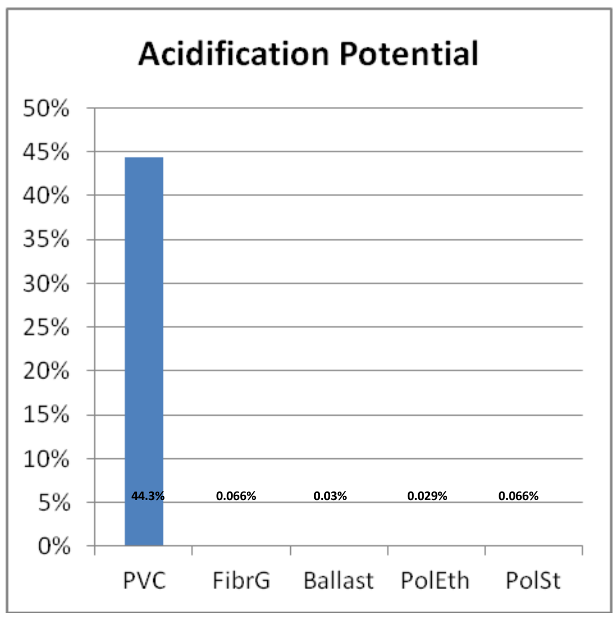
Adapted: Brown et al., 2000, p.52



Due to the high release of CO_2 gases during the manufacturing process of PVC, it is showing a significant signature in Global warming potential for the CIRS building a substantial 38.9% increase with just 10% increase in material usage.

4.1.5.4 Acidification Potential:

Gaseous pollutants that are released into the air are taken up by atmospheric precipitations and the falling "acid rain" forms an acid input due to high concentrations of NOx and SO_2, which is absorbed by plants, soil and surface waters leading to leaf damage and super acidity of the soil. . The AP of an air or water emission is calculated on the basis of its H+ equivalence effect on a mass basis (Athena IE). PVC membrane as seen before contributes to the highest environmental impact signature due to high consumption of fossil fuel & resources during manufacturing process. 10% increment in PVC membrane yields 44.3% increase in acidification potential in CIRS building, which is a very significant and concerning measure.



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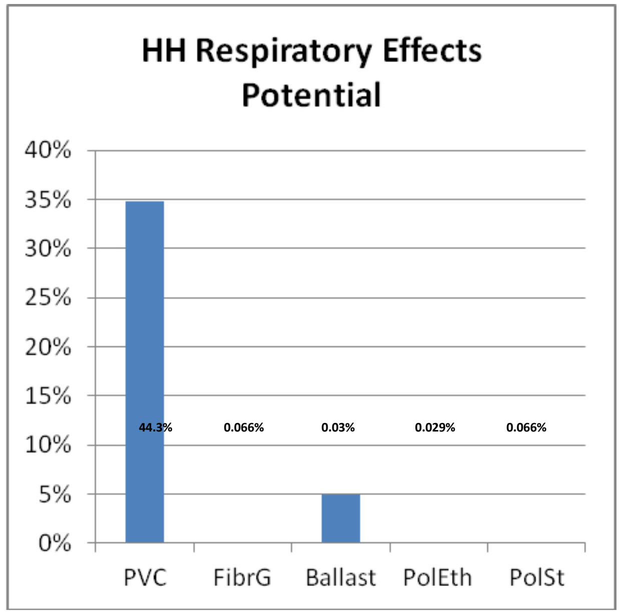
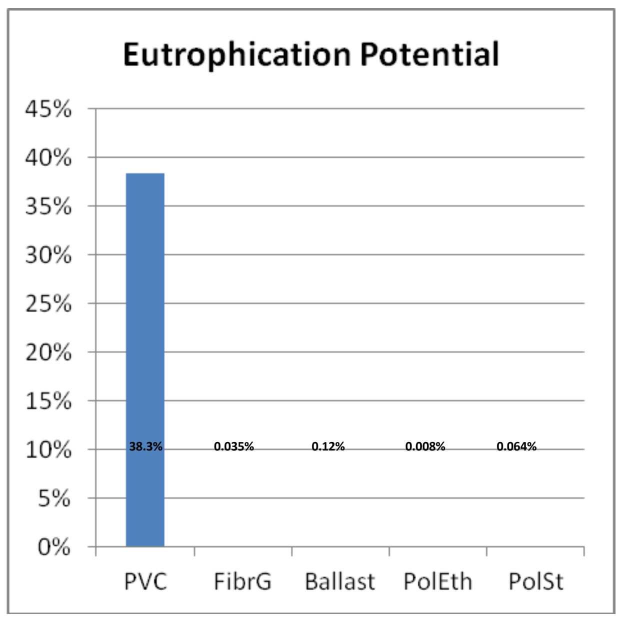
[5] Tee S, Nursultanov Y, Vanderhout R, "An Investigation into the Life Cycle of PVC and its Alternatives using Three-Bottom-Line Assessment", UBC, 2010

4.1.5.5 Human Health Respiratory Effects Potential:



The EPA has identified "particulates" (from diesel fuel combustion) as the number one cause of human health deterioration due to their impact on the human respiratory system. The Athena Institute used TRACI's "Human Health Particulates from Mobile Sources" characterization factor, on an equivalent PM2.5 basis, in our final set of impact indicators (Athena IE). Respiratory effects are measured as (kg PM2.5 eq / kg). In our study PVC contributes to the highest respiratory effects with a significant 44.3% increase of impacts with every 10% increase in material. This is due to the high consumption of fossil fuel (which is the major contributor of particulates) during PVC manufacturing process. The other materials seem negligible in their contribution towards respiratory effects on humans.

4.1.5.6 Eutrophication Potential:



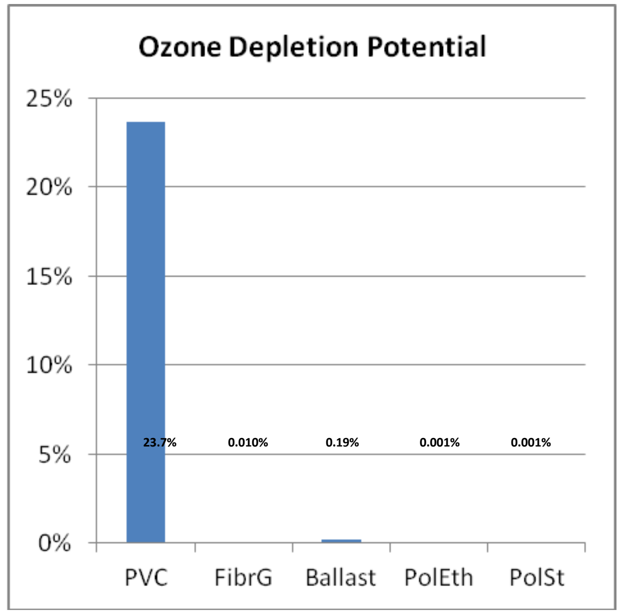
"Eutrophication is defined as an increase in the rate of supply of organic matter in an ecosystem." - Nixon, 1995

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.

In our study PVC contributes to the highest Eutrophication potential with a significant 38.3% increase of impacts with every 10% increase in material. This is due to the high consumption of fossil fuel (which may in turn toxicate the waters) during PVC manufacturing process. The other materials seem negligible in their contribution towards Eutrophication potential.

4.1.5.7 Ozone Depletion Potential:

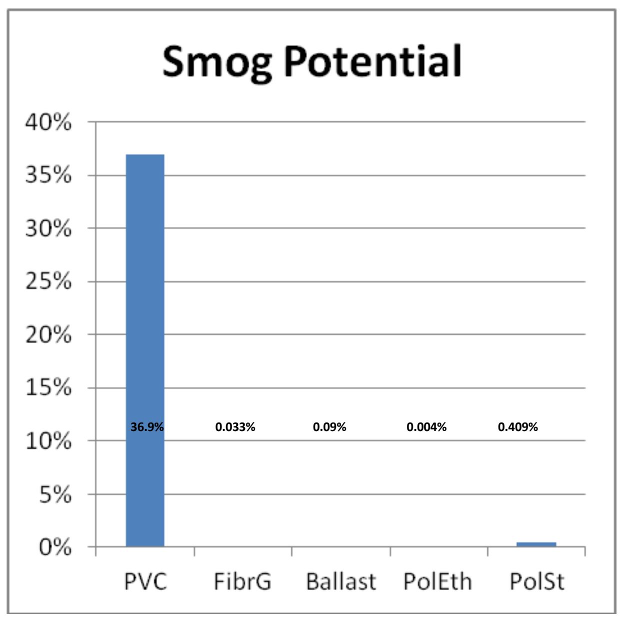
Ozone depletion potential (ODP) is a relative value that indicates the potential of a substance to destroy ozone gas. Ozone depleting substances (CFCs, HFCs, and halons) are responsible for reacting with the UV radiation and depleting the ozone layer in stratosphere. The ozone depletion potential of each of the contributing substances is characterized relative to CFC-11, with the final impact indicator indicating mass (e.g., kg) of equivalent CFC-11.



In our study PVC contributes to the highest Ozone depletion potential with a significant 23.7% increase of impacts with every 10% increase in material. This is due to the high consumption of fossil fuel (with high air emissions) during PVC manufacturing process. The other materials seem negligible in their contribution towards ODP.

4.1.5.8 Smog Potential:

Certain climatic conditions air emissions from industries and transportation gets trapped at ground level and give rise to a phenomena known as photochemical ozone creation potential (POCP). The photochemical oxidation, very often defined as summer smog, is the result of reactions that take place between nitrogen oxides (NOx) and volatile organic compounds (VOC) exposed to UV radiation. While ozone is not emitted directly, it is a product of interactions of volatile organic compounds (VOCs) and nitrogen oxides (NOx). The "smog" indicator is expressed on a mass of equivalent NOx basis.



In our study PVC contributes to the highest POCP with a significant 36.9% increase of impacts with every 10% increase in material. This is due to the high consumption of fossil fuel (with high air emissions) during PVC manufacturing process. The other materials seem negligible in their contribution towards POCP.

4.1.6 Chain of Custody:

CIRS is the first large, multi-story institutional building at the UBC to be completely constructed of ooden structure. The Structural system is constructed from Glulam framing system, supporting a solid wood deck. Over 50 per cent of the wood used in the project is certified by the Forest Stewardship Council (FSC) and the remaining is pine from forests affected by the Mountain Pine Beetles.

Material	Life cycle stage	Company name	Address	Email + Phone	Date contacted	Location	Latitude of facility	Longitude of facility	Transportation mode to facility	Transportation mode from facility	Notes
Glulam	Extraction/ Manufacturer	Western Archrib	4315, 92 Avenue, Edmonton, Alberta	Ph: 780.465.9771, email: gen@westernarchrib.com	28-Mar-12	Canel Flats	+50° 9' 17.19"	-115° 48' 28.99"	Truck	Truck	
Beetle Kill Wood	Manufacturing	Canfor	1920 Brownmiller rd, Quesnel	Ph: 604 661-5241, email: karen.anderson@canfor.com	28-Mar-12	Quesnel	+52° 58' 54.24"	-122° 29' 39.80"	Truck	Truck	Pine Beetle Lumber was extracted from many other smaller infected sites within Centeral Interior District, No record was found of all those acquisitions at the time being.

Figure 17 - Chain of Custody information

Since the major part of the building is made from wood, it was our obvious choice of material for the chain of custody exercise. Chain of Custody (CoC) is chronological documentation or paper trail, tracking the material right till its extraction point. This would give useful information to the inquirer about the origins of the material and can be related to LCA study results to measure sensitivity of regional impacts and effects of geographic variations on the product.

Due to the different species of wood used in the structural system of CIRS building, it was found very difficult to track all the different forms of lumber used in the building. We concluded on two major wooden types used in CIRS i.e. Glulam (Spruce, fir & pine) and Pine beetle infected wood. Due to the unavailability of any useful information in the drawing regarding the sourcing and manufacturing of those structural components we had to call the Architect firm to acquire the information. Busby Perkin + Will, being a prominent firm in North America were very helpful but did not had the correct information that was required; however they did managed to give the name of the Wood contractor M/s Heatherbrae, responsible for woodwork at CIRS. Sending a few emails and calling some of the engineers working there, we were able to get the required information about the manufacturer and location of extraction of the lumber for CIRS. We then contacted the saw mill, to verify the information that they were the ones who supply this specific lumber to Heatherbrae and also the location of their wood extraction source. Heatherbrae also was vigilant enough to send us the LEED submission documents for the structural wood at CIRS, as a verification of the information forwarded to us.

Type of Wood	Responsibility	Name	Location, Address
Glulam	Extraction/ Manufacturer	Western Archrib	4315, 92 Avenue, Edmonton, Alberta
Beetle Kill Wood	Manufacturing	Canfor	1920 Brownmiller rd, Quesnel

5. Functions and Impacts

5.1 Building Functions

CIRS is a pilot project for the "Campus as a Living Laboratory" initiative, which uses the infrastructure and building projects as opportunities to test demonstrate and do research on sustainable design solutions, innovative technology and clean energy.

The building is not designed to hold any particular discipline classes or lectures as in a typical institutional building; rather it was designed to accommodate a variety of different uses over the life of the building. The building mainly consists of open areas which are used for workstations, closed offices, dry lab space and meeting rooms.

The most unique feature of the building is its *wastewater treatment system*, which is located in a glass volume on the ground floor. This strategic positioning places one of the most important sustainable features of the project in a prominent and publicly visible location.

Several spaces in CIRS serve the following functions:

Office / Lab Space: The main spaces of the building are the academic spaces, located on the upper floors of the two thin wings on the north and south sides of the building. The offices have been fitted out to accommodate the requirements of the different tenant groups currently in place and include open areas of workstations, closed offices, dry lab space and meeting rooms.

Modern Green Development Auditorium: Located on the ground floor, the auditorium is the largest on campus with 450 seat capacity and fills the space between the two narrow office block wings. A living roof over the auditorium serves as an atrium for the upper floor offices.

Figure 18 - Modern Green Development Auditorium

Loop Cafe / Kitchen: Located on the ground floor the cafe serves only locally sources & seasonal foods.

BC Hydro Theatre: This is a group decision theatre on the ground floor and works as a digital multi-media black box theatre which is part of the communication aspect of the CIRS research agenda. Policy lab is another group decision place for large meetings and remote collaborations.

Commons and Student Lounges: Informal common spaces available to the public are located on the bridges of the second, third and fourth floors of the atrium. The common spaces and the student lounges in some of the office areas provide places for casual interactions, studying and socializing.

Campus Storage: UBC Classroom Services previously used the CIRS site for a small warehouse housing the short-term storage of furniture. That function is now transferred to a large storage space in the basement of the CIRS building.

Building Systems and Services Spaces: Most of the service spaces and rooms for building systems are located in the basement, including electrical rooms, pump rooms, potable water processing room and the main data and communication room.

Building Operations Center: The Building Monitoring and Assessment Lab, including the CIRS Operations Center, are located on the third floor. This is where the building and its systems are monitored and the data recorded is collected.

The building is composed of the following areas:

Functional Area Type	Gross Floor Area (ft^2)	Percentage of Total Building Area (%)
Classrooms	4938.1056	11.42
Offices/Office Spaces	6078.496	14.06
Testing labs	N/A	
Library	N/A	
Study/Research/Prep/Computer lab rooms	10285.0304	23.79
Storage rooms	2151.68	4.98
Stairwells/Halls/ Atriums	10252.7552	23.71
Washrooms/ Locker rooms	430.336	1.0
Mechanical rooms	2883.2512	6.67
Auditorium/ Lecture Halls	6218.3552	14.38
Total Area	**43238 ft^2**	

Table 7 – Functional Areas

5.2 Functional Unit:

Functional unit is primarily used to provide normalization reference to the input and output data (mathematically) for the LCA study. Therefore the functional unit shall be clearly defined and measurable. Different systems can be compared with each other on the basis of similar functions and measured by the same functional unit(s) in the form of their reference flows. Any assumptions or additional information utilized to develop the functional units for any process system should be documented and made explicit in the study.

The functional units used in this study to normalize the LCA results for the CIRS Building include:

5.2.1 Per generic post-secondary academic building square foot constructed (e.g. Impact/building gross area):

Life Cycle Stages **Lif eCycle Impact Categories**	Manufacturing	Construction	Maintenance	End-of-Life	Total
Fossil Fuel Consumption MJ	317.96704	22.68563	132.73834	14.20012	487.59113
Weighted Resource Use kg	146.75390	0.53042	16.08089	0.33442	163.69963
Global Warming Potential (kg CO2 eq)	27.87589	1.42207	12.84668	0.96420	43.10884
Acidification Potential (moles of H+ eq)	12.05524	0.61119	5.65710	0.13091	18.45445
HH Respiratory Effects Potential (kg PM2.5 eq)	0.10388	0.00072	0.08107	0.00015	0.18581
Eutrophication Potential (kg N eq)	0.01231	0.00062	0.00566	0.00011	0.01870
Ozone Depletion Potential (kg CFC-11 eq)	7.73E-08	3.59E-11	5.99E-08	4.22E-11	1.37E-07
Smog Potential (kg NOx eq)	0.11781	0.01418	0.05292	0.00257	0.18748
Total Area 66123.00 ft^2	**504.88606**	**25.26482**	**167.46266**	**15.63249**	**713.24604**

The Table-8 shows the environmental impacts distributed over the gross area of the CIRS building; this normalization of the impacts would allow comparative assertions of the impacts with other buildings on the basis of gross area. This generalized impact per area distribution can be compared to any building area of similar functionality.

5.2.2 Per specific post-secondary academic building square foot constructed (e.g. Impact/classroom gross area)

The Table-9 shows the environmental impacts distributed over the gross functional space area of the CIRS building; this normalization of the impacts would allow comparative assertions of the impacts with other functional spaces of different buildings. This generalized impact per functional space area distribution can be compared to any other functional area.

Table 8 – Impacts per CIRS gross area

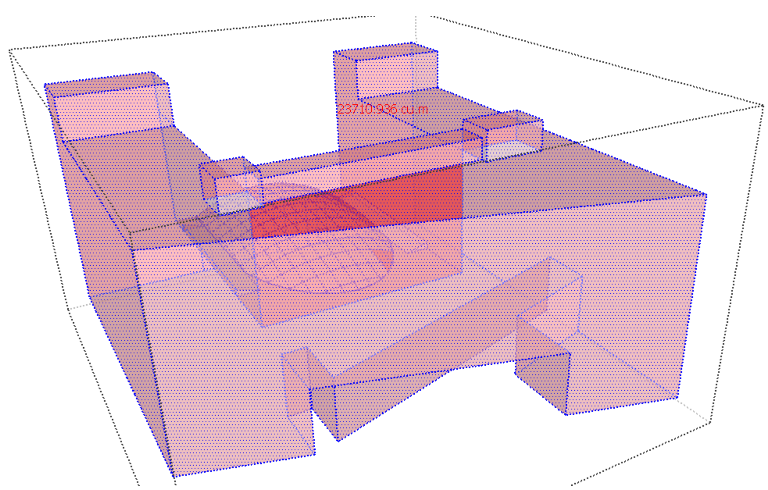
Classroom impacts can be compared to any other classroom, given that the goal and scope of that study falls close to the goal & scope of CIRS LCA study. The purpose of the reference flows is to translate the abstract functional unit into specific product flows for each of the compared systems, so that product alternatives are compared on an equivalent basis, reflecting the actual consequences of the potential product substitution.

Building Functional Spaces		**Classroom**	**Office spaces/ meeting rooms**	**Study/ research/ Computer lab**	**Storage rooms**	**Stairwell/ Atrium/ cafe'**	**Washroom s / locker rooms**	**Mechanical Rooms**	**Auditorium/ lecture halls**
Lif Cycle Impact Categories	Area %age	11.42%	14.06%	23.79%	4.98%	23.71%	1.00%	6.67%	14.38%
	Total Impacts								
Fossil Fuel Consumption **MJ**	32240988.16	3681920.85	4533082.94	7670131.08	1605601.21	7644338.29	322409.88	2150473.91	4636254.10
Weighted Resource Use **kg**	10824310.6	1236136.27	1521898.07	2575103.49	539050.67	2566444.04	108243.11	721981.52	1556535.86
Global Warming Potential **(kg CO2 eq)**	2850485.918	325525.49	400778.32	678130.60	141954.20	675850.21	28504.86	190127.41	409899.88
Acidification Potential **(moles of H+ eq)**	1220263.403	139354.08	171569.03	290300.66	60769.12	289324.45	12202.63	81391.57	175473.88
HH Respiratory Effects Potential **(kg PM2.5 eq)**	12286.23565	1403.09	1727.44	2922.90	611.85	2913.07	122.86	819.49	1766.76
Eutrophication Potential **(kg N eq)**	1236.551418	141.21	173.86	294.18	61.58	293.19	12.37	82.48	177.82
Ozone Depletion Potential **(kg CFC-11 eq)**	0.009077895	1.04E-03	1.28E-03	2.16E-03	4.52E-04	2.15E-03	9.08E-05	6.05E-04	1.31E-03
Smog Potential **(kg NOx eq)**	12396.99779	1415.74	1743.02	2949.25	617.37	2939.33	123.97	826.88	1782.69
Functional Total Area 43238.0 0 ft2	**Total Impacts / functional space**	**5385896.73**	**6630972.68**	**11219832.16**	**2348666.00**	**11182102.58**	**471619.68**	**3145703.26**	**6781890.98**

Table 9 – Impacts per CIRS functional space area

5.2.3 Per generic post-secondary academic building cubic foot constructed (e.g. Impact/building gross volume)

The Table-10 shows the environmental impacts distributed over the building volume of the CIRS building; this normalization of the impacts would allow comparative assertions of the impacts with other functional spaces of different buildings in terms of spatial parameters (volumes). This generalized impact per building volume distribution can be compared to any other functional volume.



Environmental impacts can be compared to any other buildings spatially, given that the goal and scope of that study falls close to the goal & scope of CIRS LCA study. Spatial comparison provides further elaboration towards distribution of the environmental impacts relative to the form and physical entity of the built environment.

Life Cycle Stages Lif Cycle Impact Categories	Total building Impacts	Manufacturing Impact/ft^3	Construction Impact/ft^3	Maintenance Impact/ft^3	End-of-Life Impact/ft^3	Total Impact/ft^3
Fossil Fuel Consumption MJ	32240988.16	25.12937	1.79288	10.49049	1.12226	38.53499
Weighted Resource Use kg	10824310.6	11.59816	0.04192	1.27089	0.02643	12.93740
Global Warming Potential (kg CO2 eq)	2850485.918	2.20307	0.11239	1.01529	0.07620	3.40695
Acidification Potential (moles of H+ eq)	1220263.403	0.95274	0.04830	0.44709	0.01035	1.45848
HH Respiratory Effects Potential (kg PM2.5 eq)	12286.23565	0.00821	0.00006	0.00641	0.00001	0.01468
Eutrophication Potential (kg N eq)	1236.551418	0.00097	0.00005	0.00045	0.00001	0.00148
Ozone Depletion Potential (kg CFC-11 eq)	0.009077895	6.11E-09	2.84E-12	4.73E-09	3.34E-12	1.09E-08
Smog Potential (kg NOx eq)	12396.99779	0.00931	0.00112	0.00418	0.00020	0.01482
Total Volume 836667.86 ft3	**47161967.87**	**39.90183**	**1.99671**	**13.23480**	**1.23546**	**56.36881**

Table 10 – Impacts per CIRS volume

5.2.4 Per post-secondary academic building energy use

Since CIRS is designed specifically as a test bed and demonstration platform (proof of concept) for net-zero energy and regenerative building technologies, it would be quite informative to find out the environmental impacts of the building per energy utilized during its operations. However, to make our study simpler and to allocate custody of impacts, we have considered transferring all the environmental impacts associated with manufacturing and construction of CIRS building to the operations and maintenance stage. This sort of functional distribution would be beneficial in comparing CIRS LCA study to other green building per their energy usage and also to other buildings. This would ascertain environmental impacts of sustainable and non-sustainable buildings against a baseline of their actual performance in terms of energy utility.

CIRS is unique in this aspect as it has standalone energy consumption as well as is responsible of exchanging heat energy with adjacent EOS building. We have considered the standalone yearly energy consumption as this would give a generic baseline to be comparable with other buildings. Table 11 illustrates distribution

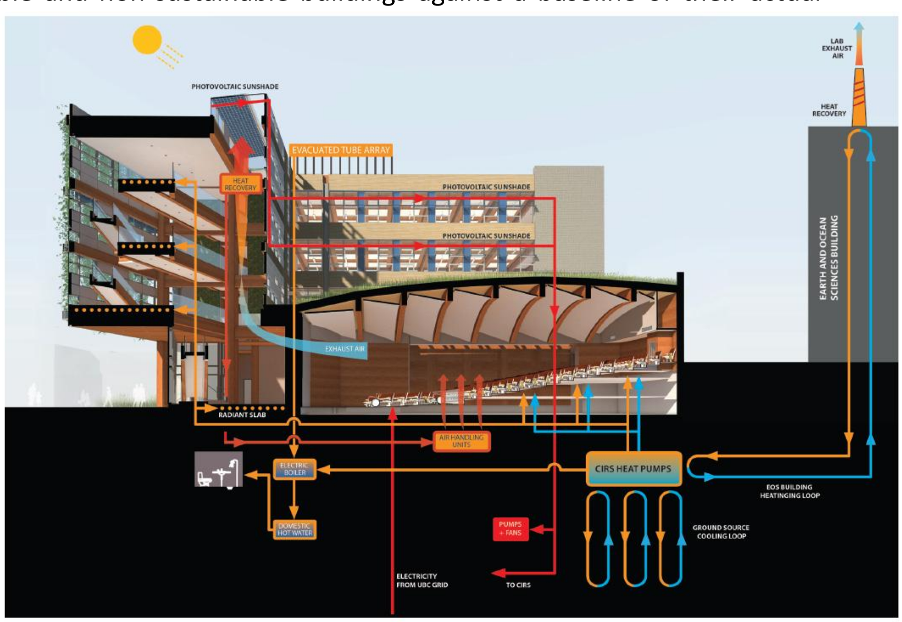


Figure 16 – CIRS Heating system highlighting heat exchange between EOS

of environmental impacts per impact categories per stand alone energy consumption of CIRS.

Life Cycle Stages Lif Cycle Impact Categories	Total building Impacts	Manufacturing Impact/(ekWh/yr)	Construction Impact/(ekWh/yr)	Maintenance Impact/(ekWh/yr)	End-of-Life Impact/(ekWh/yr)	Total Impact/(ekWh/yr)
Fossil Fuel Consumption MJ	32240988.16	53.64462	3.82732	22.39445	2.39572	82.26211
Weighted Resource Use kg	10824310.6	24.75903	0.08949	2.71303	0.05642	27.61797
Global Warming Potential (kg CO2 eq)	2850485.918	4.70298	0.23992	2.16738	0.16267	7.27295
Acidification Potential (moles of H+ eq)	1220263.403	2.03385	0.10312	0.95442	0.02209	3.11347
HH Respiratory Effects Potential (kg PM2.5 eq)	12286.23565	0.01752	0.00012	0.01368	0.00002	0.03135
Eutrophication Potential (kg N eq)	1236.551418	0.00208	0.00010	0.00095	0.00002	0.00316
Ozone Depletion Potential (kg CFC-11 eq)	0.009077895	1.30E-08	6.06E-12	1.01E-08	7.12E-12	2.32E-08
Smog Potential (kg NOx eq)	12396.99779	0.01988	0.00239	0.00893	0.00043	0.03163
Total Area 391930.00 ekWh/yr		85.17996	4.26246	28.25284	2.63738	120.33263

Table 11 – Impacts per CIRS yearly standalone energy consumption

Some of the references to highlight the importance of comparative assertion of environmental impacts per energy usage of the buildings.

"Buildings accounted for 38.9 percent of total U.S. energy consumption in 2005. Residential buildings accounted for 53.7 percent of that total, while commercial buildings accounted for the other 46.3 percent. Buildings in contribute 38.9 percent of the nation's total carbon dioxide emissions, including 20.8 percent from the residential sector and 18.0 percent from the commercial sector (2008)."[6]

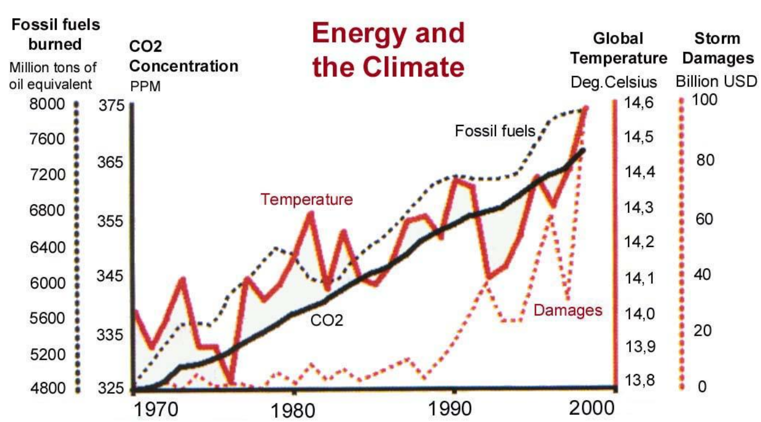


Figure 17 – Impact of energy use on environmental changes & impacts
http://energysavingnow.com/energytoday/environment.shtml

6 Emissions of Greenhouse Gases in the United States 2007, DOE/EIA-0573(2007), Energy Information Administration, U.S. Department of Energy December 2008 http://www.eia.doe.gov/oiaf/1605/ggrpt/index.html

6. Conclusion

The Life cycle assessment of CIRS building was carried out to built up a benchmark for future green buildings at UBC campus as well as a proof of claim of sustainability and net-zero energy performance. To achieve those goals a formulated approach was taken from quantity take-off using different state-of-art software, to preparing as thorough an inventory of building components & assemblies as was possible from the available information, modeling was done with Athena Impact Estimator which has one of the largest life cycle inventory database in North America. Assumptions and limitations of the software as well as the data were document in order to make the process transparent for any future reference or comparisons, this included explicit documentation in the form of input and assumption documents appendix to this report.

Results from the life cycle assessment produced considerable information to manipulate and interpolate the findings into coherent and meaningful parameters. A comprehensive Bill of Materials was generated from the Athena IE which included the quantities from the input document as well as other material quantities generated by Athena LCI database, given the manufacturing process of those building assemblies. A set of 5 most significant materials was selected to study the effect of change of those materials on building environmental impact footprint. Sensitivity analysis was carried out to interpret and juxtapose the results of that material change, which showed that PVC membrane used as water proofing of roof structure bore the highest change signature on environmental impacts throughout the building life stages.

Impact Estimator summarizes the impacts under 8 categories showing distribution of through the life cycle stages of the building. As site preparation / existing facilities and waste disposal was not part of the study, life cycle stages were cut off at end of life process (demolition) and does not include any impacts associated with product reuse or recycling.

From the analysis it is evident that CIRS stand up to the test of being sustainable and contributing positively towards its environment.

This LCA study of the CIRS Building can be further developed and improved by further elaborating the scope of the study and filling the missing or ambiguous data gaps, marring the current analysis. Performing more detailed takeoffs that include assemblies such as mechanical, HVAC, flooring, finishes, and other renewable energy outfits like Photovoltaic equipment, would also result in a more representative model of the building. The simplifications employed during modeling could also be refined to provide more accurate findings. As for impact assessment, using a more thorough and extensive LCA software that can model more complex scenarios in a transparent way, such as SimaPro, can yield more reliable results.

7. References

Canadian Standards Association. (2006). *CSA Standard CAN/CSA-ISO 14040:06.* International Organization for Standardization (ISO).

Canadian Standards Association. (2006). *CSA Standard CAN/CSA-ISO 14044:06.* International Organization for Standardization (ISO).

Athena Sustainable Materials Institute, "Life Cycle inventory of ICI roofing systems: Onsite construction effects", Ottawa 2001

http://www.eia.doe.gov/oiaf/1605/ggrpt/index.html

8. Appendix A – Impact Estimator Input Document

Assembly Group	Assembly Type	Assembly Name	Input Fields	Input Values	
				Known/Measured	IE Inputs
1 Foundations					
	1.2 Concrete SoG				
		1.2.1 SoG_Mech Mat_150mm			
			Length (ft)	73.79672	90.42
			Width (ft)	73.79672	90.42
			Thickness (in)	6	4
			Concrete (psi)	4350	4000
			Concrete flyash %	30	25
			Rebar	10M	10M
		1.2.2 SoG_Mat_1_150mm_Auditorium			
			Length (ft)	10.8	13.24
			Width (ft)	10.8	13.24
			Thickness (in)	6	4
			Concrete (psi)	4350	4000
			Concrete flyash %	30	25
			Rebar		
		1.2.3 SoG_Mat_2_150mm_Auditorium			
			Length (ft)	16.2	19.86
			Width (ft)	16.2	19.86
			Thickness (in)	6	4
			Concrete (psi)	4350	4000
			Concrete flyash %	30	25
			Rebarr		
	1.3 Concrete Footing				
		1.3.1 Elevator_Footing_NorthWest			
			Length (ft)	4.27	4.27
			Width (ft)	4.27	4.27
			Thickness (in)	12	12
			Concrete (psi)	4350	4000
			Concrete flyash %	50	35
			Rebar	15M	15M
		1.3.1 Elevator_Footing_NorthEast			
			Length (ft)	4.1	4.1
			Width (ft)	4.1	4.1
			Thickness (in)	12	12
			Concrete (psi)	4350	4000
			Concrete flyash %	50	35

			Rebar	15M	15M
		1.3.2 PullPit_Footing_200mm	Length (ft)	3.34	3.34
			Width (ft)	1.8	1.8
			Thickness (in)	8	8
			Concrete (psi)	4350	4000
			Concrete flyash %	50	35
			Rebar	15M	15M
		1.3.3 Footing_F1 (Strip)	Length (ft)	77.75	77.75
			Width (ft)	4	4
			Thickness (in)	10	10
			Concrete (psi)	4350	4000
			Concrete flyash %	50	35
			Rebar	20M	20M
		1.3.4 Footing_F2 (Strip)	Length (ft)	212.082	212.082
			Width (ft)	4.333	4.333
			Thickness (in)	10	10
			Concrete (psi)	4350	4000
			Concrete flyash %	50	35
			Rebar	20M	20M
				25M	20M
		1.3.5 Footing_F3 (Strip)	Length (ft)	104.21	104.21
			Width (ft)	2.1667	2.1667
			Thickness (in)	8	8
			Concrete (psi)	4350	4000
			Concrete flyash %	50	35
			Rebar	15M	15M
		1.3.6 Footing_F4	Length (ft)	40.002	40.002
			Width (ft)	40.002	40.002
			Thickness (in)	12	12
			Concrete (psi)	4350	4000
			Concrete flyash %	50	35
			Rebar	25M	20M
		1.3.7 Footing_F5	Length (ft)	12	12
			Width (ft)	12	12
			Thickness (in)	14	14
			Concrete (psi)	4350	4000
			Concrete flyash %	50	35
			Rebar	25M	20M
2 Walls					
	2.1 Cast In Place				
		2.1.1 Wall_Cast-in-place_W1-W2_Basement			
			Length (m)	127	127
			Height (m)	4.2	4.2
			Thickness (mm)	300	-
			Concrete (MPa)	30	30

	Concrete flyash %	-	average
	Rebar	15M	15M
Door Opening	Number of Doors	16	16
	Door Type	Steel Interior Door	Steel Interior Door
2.1.2 Wall_Cast-in-place_E1-W1_Basement			
	Length (m)	93	93
	Height (m)	4.2	4.2
	Thickness (mm)	300	-
	Concrete (MPa)	30	30
	Concrete flyash %	-	average
	Rebar	15M & 20M	15M
Envelope	Category	Insulation	Insulation
	Material	R20 CT Insultation	Expanded Plystyrene
	Thickness (mm)	-	100
	Category	Vapour Barrier	Vapour Barrier
	Material	Dampproofing	6 mil poly
	Thickness (mm)	-	-
2.1.3 Wall_Cast-in-place_E1-SW5_Basement			
	Length (m)	70	81.667
	Height (m)	4.2	4.2
	Thickness (mm)	350	300
	Concrete (MPa)	30	30
	Concrete flyash %	-	average
	Rebar	20M	20M
Envelope	Category	Insulation	Insulation
	Material	R20 CT Insultation	Expanded Plystyrene
	Thickness (mm)	-	100
	Category	Vapour Barrier	Vapour Barrier
	Material	Dampproofing	6 mil poly
	Thickness (mm)	-	-
Door Opening	Number of Doors	4	4
	Door Type	Steel Interior Door	Steel Interior Door
2.1.4 Wall_Cast-in-place_E1-SW4_Basement			
	Length (m)	36	36
	Height (m)	4.2	4.2
	Thickness (mm)	300	300
	Concrete (MPa)	30	30
	Concrete flyash %	-	average
	Rebar	20M	20M
Envelope	Category	Insulation	Insulation
	Material	R20 CT Insultation	Expanded Plystyrene
	Thickness (mm)	-	100
	Category	Vapour Barrier	Vapour Barrier
	Material	Dampproofing	6 mil poly
	Thickness (mm)	-	-
2.1.5 Wall_Cast-in-place_W1-W3_Basement			
	Length (m)	25	25
	Height (m)	4.2	4.2
	Thickness (mm)	300	300
	Concrete (MPa)	30	30
	Concrete flyash %	-	average

			Rebar	15M	15M
		Door Opening	Number of Doors	4	4
			Door Type	Steel Interior Door	Steel Interior Door
		2.1.6 Wall_Cast-in-place_W1-SW1_Basement			
			Length (m)	24	24
			Height (m)	4.2	4.2
			Thickness (mm)	300	300
			Concrete (MPa)	30	30
			Concrete flyash %	-	average
			Rebar	20M	20M
		Door Opening	Number of Doors	2	2
			Door Type	Steel Interior Door	Steel Interior Door
		2.1.7 Wall_Cast-in-place_E1-SW3_Basement			
			Length (m)	14	14
			Height (m)	4.2	4.2
			Thickness (mm)	300	300
			Concrete (MPa)	30	30
			Concrete flyash %	-	average
			Rebar	15M & 20M	15M
		Envelope	Category	Insulation	Insulation
			Material	R20 CT Insultation	Polystyrene Expanded
			Thickness (mm)	-	100
			Category	Vapour Barrier	Vapour Barrier
			Material	Dampproofing	6 mil poly
			Thickness (mm)	-	-
		2.1.8 Wall_Cast-in-place_W1-SW2_Basement			
			Length (m)	13	26
			Height (m)	4.2	4.2
			Thickness (mm)	600	300
			Concrete (MPa)	30	30
			Concrete flyash %	-	average
			Rebar	20M	20M
		2.1.9 Wall_Cast-in-place_W1-SW1_Ground			
			Length (m)	63	63
			Height (m)	6.5	6.5
			Thickness (mm)	300	300
			Concrete (MPa)	30	30
			Concrete flyash %	-	average
			Rebar	20M	20M
		Door Opening	Number of Doors	5	5
			Door Type	Solid Wood	Solid Wood Door
		2.1.10 Wall_Cast-in-place_E1-SW4_Ground			
			Length (m)	43	43
			Height (m)	4.2	4.2
			Thickness (mm)	300	300
			Concrete (MPa)	30	30
			Concrete flyash %	-	average
			Rebar	20M	20M
		Envelope	Category	Insulation	Insulation
			Material	R20 CT Insultation	Polystyrene Expanded
			Thickness (mm)	-	100

	Category	Vapour Barrier	Vapour Barrier
	Material	Dampproofing	6 mil poly
	Thickness (mm)	-	-
Window Opening	Number of Windows	8	8
	Total Window Area (ft2)	4.9	4.9
	Frame Type	Fixed, Aluminum Frame	Fixed, Aluminum Frame
	Glazing Type	Low E Argon Filled Glazing	Low E Tin Argon Filled Glazing
Door Opening	Number of Doors	1	1
	Door Type	Solid Wood	Solid Wood Door
2.1.11 Wall_Cast-in-place_E3.1-SW4_Ground			
	Length (m)	42	42
	Height (m)	4.2	4.2
	Thickness (mm)	300	300
	Concrete (MPa)	30	30
	Concrete flyash %	-	average
	Rebar	20M	20M
Steel Stud	Sheathing Type	-	None
	Stud Spacing	400oc	600oc
	Stud Weight	-	Light (25Ga)
	Stud Thickness	-	38 x 92
Envelope	Category	Cladding	Cladding
	Material	90 sawn face concrete masonry	Brick - concrete
	Thickness (mm)	-	-
	Category	Paint	Paint
	Material	Elastomeric paint	Varnish solvent based
	Thickness (mm)	-	-
	Category	Vapour Barrier	Vapour Barrier
	Material	Dampproofing	6 mil poly
	Thickness (mm)	-	-
	Category	Insulation	Insulation
	Material	R20 Mineral wool	Rockwool Batt
	Thickness (mm)	119	140
	Category	Gypsum Board	Gypsum Board
	Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
	Thickness (mm)	-	-
Door Opening	Number of Doors	2	2
	Door Type	Glass Panel	Aluminum Exteror Door, 80% glazing
2.1.12 Wall_Cast-in-place_Wood studs_E2_Ground			
	Length (m)	33	33
	Height (m)	4.2	4.2
	Thickness (mm)	300	300
	Concrete (MPa)	30	30
	Concrete flyash %	-	average
	Rebar	15M & 20M	20M
Wood Stud	Wall Type	Non leadbearing	Non leadbearing
	Sheathing Type	19 solid wood slats	Plywood
	Study Spacing	600oc	600oc
	Stud Type	Kiln dried	Kiln dried
	Stud Thickness	38 x 89	38 x 89

		Steel Stud	Sheathing Type	-	None
			Stud Spacing	600oc	600oc
			Stud Weight	-	Light (25Ga)
			Stud Thickness	-	38 x 92
		Envelope	Category	Vapour Barrier	Vapour Barrier
			Material	Dampproofing	6 mil poly
			Thickness (mm)	-	-
			Category	Insulation	Insulation
			Material	R20 CT Insultation	Polystyrene Expanded
			Thickness (mm)	-	100
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
			Thickness (mm)	-	-
			Category	Black out fabric	-
			Material	-	-
			Thickness (mm)	-	-
		2.1.13 Wall_Cast-in-place_E1-W1_Ground			
			Length (m)	33	33
			Height (m)	5	5
			Thickness (mm)	300	300
			Concrete (MPa)	30	30
			Concrete flyash %	-	average
			Rebar	15M & 20M	20M
		Envelope	Category	Vapour Barrier	Vapour Barrier
			Material	Dampproofing	6 mil poly
			Thickness (mm)	-	-
			Category	Insulation	Insulation
			Material	R20 CT Insultation	Polystyrene Expanded
			Thickness (mm)	-	100
		Window Opening	Number of Windows	5	5
			Total Window Area (ft2)	3.1	3.1
			Frame Type	Fixed, Aluminum Frame	Fixed, Aluminum Frame
			Glazing Type	Low E Argon Filled Glazing	Low E Tin Argon Filled Glazing
		Door Opening	Number of Doors	1	1
			Door Type	Glass Panel	Aluminum Exteror Door, 80% glazing
		2.1.14 Wall_Cast-in-place_W1-W2_Ground			
			Length (m)	27	27
			Height (m)	2.5	2.5
			Thickness (mm)	200	300
			Concrete (MPa)	30	30
			Concrete flyash %	-	average
			Rebar	15M	15M
		2.1.15 Wall_Cast-in-place_Theatre roundback_Ground			
			Length (m)	17	17
			Height (m)	4.2	4.2
			Thickness (mm)	250	300
			Concrete (MPa)	30	30

			Concrete flyash %	-	average
			Rebar	15M	15M
		Envelope	Category	Vapour Barrier	Vapour Barrier
			Material	Dampproofing	6 mil poly
			Thickness (mm)	-	-
			Category	Insulation	Insulation
			Material	R20 CT Insultation	Polystyrene Expanded
			Thickness (mm)	-	100
		2.1.16 Wall_Cast-in-place_Retaining_Ground			
			Length (m)	15	13
			Height (m)	1.5	1.5
			Thickness (mm)	250	300
			Concrete (MPa)	30	30
			Concrete flyash %	-	average
			Rebar	-	15M
		2.1.17 Wall_Cast-in-place_E1-SW5_Ground			
			Length (m)	16	19
			Height (m)	5.3	5.3
			Thickness (mm)	350	300
			Concrete (MPa)	30	30
			Concrete flyash %	-	average
			Rebar	20M	20M
		Envelope	Category	Vapour Barrier	Vapour Barrier
			Material	Dampproofing	6 mil poly
			Thickness (mm)	-	-
			Category	Insulation	Insulation
			Material	R20 CT Insultation	Polystyrene Expanded
			Thickness (mm)	-	100
		Door Opening	Number of Doors	1	1
			Door Type	Glass Panel	Aluminum Exteror Door, 80% glazing
		2.1.18 Wall_Cast-in-place_W1-SW2_Ground			
			Length (m)	13	26
			Height (m)	4.2	4.2
			Thickness (mm)	600	300
			Concrete (MPa)	30	30
			Concrete flyash %	-	average
			Rebar	20M	20M
		2.1.19 Wall_Cast-in-place_E1-W1_Level 02			
			Length (m)	18	18
			Height (m)	5.3	5.3
			Thickness (mm)	300	300
			Concrete (MPa)	30	30
			Concrete flyash %	-	average
			Rebar	15M & 20M	20M
		Envelope	Category	Vapour Barrier	Vapour Barrier
			Material	Dampproofing	6 mil poly
			Thickness (mm)	-	-
			Category	Insulation	Insulation
			Material	R20 CT	Polystyrene Expanded

			Insultation	
		Thickness (mm)	-	100
	Window Opening	Number of Windows	5	5
		Total Window Area (ft2)	3.1	3.1
		Frame Type	Fixed, Aluminum Frame	Fixed, Aluminum Frame
		Glazing Type	Low E Argon Filled Glazing	Low E Tin Argon Filled Glazing
	2.1.20 Wall_Cast-in-place_W1-W2_Level 02			
		Length (m)	6	6
		Height (m)	5.3	5.3
		Thickness (mm)	200	300
		Concrete (MPa)	30	30
		Concrete flyash %	-	average
		Rebar	15M	15M
2.2 Steel Stud				
	2.2.1 Wall_Steel stud_WA7_Basement			
		Length (ft)	45	45
		Height (ft)	4.2	4.2
		Sheathing Type	None	None
		Stud Spacing	600oc	600oc
		Stud Weight	-	Light (25Ga)
		Stud Thickness	152	152
	Envelope	Category	Gypsum Board	Gypsum Board
		Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
		Thickness	-	-
		Category	Gypsum Board	Gypsum Board
		Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
		Thickness	-	-
	Door Opening	Number of Doors	2	2
		Door Type	Solid Wood	Solid Wood Door
	2.2.2 Wall_Steel stud_WA7/7.2_Ground			
		Length (ft)	136	136
		Height (ft)	6.5	6.5
		Sheathing Type	None	None
		Stud Spacing	600oc	600oc
		Stud Weight	-	Light (25Ga)
		Stud Thickness	152	152
	Envelope	Category	Gypsum Board	Gypsum Board
		Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
		Thickness	-	-
		Category	Gypsum Board	Gypsum Board
		Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
		Thickness	-	-
		Category	Insulation	Insulation
		Material	Acoustic	Fiberglass Batt
		Thickness (mm)	-	152
	Door Opening	Number of Doors	17	17
		Door Type	Solid Wood	Solid Wood Door
	2.2.3 Wall_Steel stud_bathroom_Ground			

	Length (ft)	43	43
	Height (ft)	2.5	2.5
	Sheathing Type	-	None
	Stud Spacing	-	600oc
	Stud Weight	-	Light (25Ga)
	Stud Thickness	-	152
Envelope	Category	Gypsum Board	Gypsum Board
	Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
	Thickness	-	-
	Category	Ceramic wall tiles (CT-3 to 10)	-
	Material	-	-
	Thickness	-	-
Door Opening	Number of Doors	2	2
	Door Type	Solid Wood	Solid Wood Door
2.2.4 Wall_Steel stud_W14_Ground			
	Length (ft)	14	14
	Height (ft)	5.3	5.3
	Sheathing Type	-	None
	Stud Spacing	610oc	600oc
	Stud Weight	-	Light (25Ga)
	Stud Thickness	39 x 64	38 x 92
Envelope	Category	Gypsum Board	Gypsum Board
	Material	1" GWB X-TYP	Gypsum Moisture Resistant 1/2"
	Thickness	-	-
	Category	-	Gypsum Board
	Material	-	Gypsum Moisture Resistant 1/2"
	Thickness	-	-
	Category	Insulation	Insulation
	Material	Acoustic	Fiberglass Batt
	Thickness (mm)	-	64
2.2.5 Wall_Steel stud_WA7_Level 02			
	Length (ft)	44	44
	Height (ft)	4.2	4.2
	Sheathing Type	None	None
	Stud Spacing	600oc	600oc
	Stud Weight	-	Light (25Ga)
	Stud Thickness	39 x 152	38 x 152
Envelope	Category	Gypsum Board	Gypsum Board
	Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
	Thickness	-	-
	Category	Gypsum Board	Gypsum Board
	Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
	Thickness	-	-
Door Opening	Number of Doors	5	5
	Door Type	Solid Wood	Solid Wood Door
2.2.6 Wall_Steel stud_bathroom_Level 02			
	Length (ft)	10	10
	Height (ft)	4.2	4.2
	Sheathing Type	-	None

			Stud Spacing	-	600oc
			Stud Weight	-	Light (25Ga)
			Stud Thickness	-	152
		Envelope	Category	Gypsum Board	Gypsum Board
			Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
			Thickness	-	-
			Category	Ceramic wall tiles (CT-3 to 10)	-
			Material	-	-
			Thickness	-	-
		2.2.7 Wall_Steel stud_W14_Level 02			
			Length (ft)	8	8
			Height (ft)	4.2	4.2
			Sheathing Type	-	None
			Stud Spacing	610oc	600oc
			Stud Weight	-	Light (25Ga)
			Stud Thickness	39 x 64	38 x 92
		Envelope	Category	Gypsum Board	Gypsum Board
			Material	1" GWB X-TYP	Gypsum Moisture Resistant 1/2"
			Thickness	-	-
			Category	-	Gypsum Board
			Material	-	Gypsum Moisture Resistant 1/2"
			Thickness	-	-
			Category	Insulation	Insulation
			Material	Acoustic	Fiberglass Batt
			Thickness (mm)	-	64
		2.2.8 Wall_Steel stud_WA7_Level 03			
			Length (ft)	44	44
			Height (ft)	4.2	4.2
			Sheathing Type	None	None
			Stud Spacing	600oc	600oc
			Stud Weight	-	Light (25Ga)
			Stud Thickness	39 x 152	38 x 152
		Envelope	Category	Gypsum Board	Gypsum Board
			Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
			Thickness	-	-
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
			Thickness	-	-
		Door Opening	Number of Doors	3	3
			Door Type	Solid Wood	Solid Wood Door
		2.2.9 Wall_Steel stud_bathroom_Level 03			
			Length (ft)	10	10
			Height (ft)	4.2	4.2
			Sheathing Type	-	None
			Stud Spacing	-	600oc
			Stud Weight	-	Light (25Ga)
			Stud Thickness	-	152
		Envelope	Category	Gypsum Board	Gypsum Board
			Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"

			Thickness	-	-
			Category	Ceramic wall tiles (CT-3 to 10)	-
			Material	-	-
			Thickness	-	-
		2.2.10 Wall_Steel stud_W14_Level 03			
			Length (ft)	8	8
			Height (ft)	4.2	4.2
			Sheathing Type	-	None
			Stud Spacing	610oc	600oc
			Stud Weight	-	Light (25Ga)
			Stud Thickness	39 x 64	38 x 92
		Envelope	Category	Gypsum Board	Gypsum Board
			Material	1" GWB X-TYP	Gypsum Moisture Resistant 1/2"
			Thickness	-	-
			Category	-	Gypsum Board
			Material	-	Gypsum Moisture Resistant 1/2"
			Thickness	-	-
			Category	Insulation	Insulation
			Material	Acoustic	Fiberglass Batt
			Thickness (mm)	-	64
		2.2.11 Wall_Steel stud_WA7_Level 04			
			Length (ft)	44	44
			Height (ft)	4.2	4.2
			Sheathing Type	None	None
			Stud Spacing	600oc	600oc
			Stud Weight	-	Light (25Ga)
			Stud Thickness	39 x 152	38 x 152
		Envelope	Category	Gypsum Board	Gypsum Board
			Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
			Thickness	-	-
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
			Thickness	-	-
		Door Opening	Number of Doors	3	3
			Door Type	Solid Wood	Solid Wood Door
		2.2.12 Wall_Steel stud_bathroom_Level 04			
			Length (ft)	10	10
			Height (ft)	4.2	4.2
			Sheathing Type	-	None
			Stud Spacing	-	600oc
			Stud Weight	-	Light (25Ga)
			Stud Thickness	-	152
		Envelope	Category	Gypsum Board	Gypsum Board
			Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
			Thickness	-	-
			Category	Ceramic wall tiles (CT-3 to 10)	-
			Material	-	-
			Thickness	-	-
		2.2.13 Wall_Steel stud_W14_Level 04			

			Length (ft)	8	8
			Height (ft)	4.2	4.2
			Sheathing Type	-	None
			Stud Spacing	610oc	600oc
			Stud Weight	-	Light (25Ga)
			Stud Thickness	39 x 64	38 x 92
		Envelope	Category	Gypsum Board	Gypsum Board
			Material	1" GWB X-TYP	Gypsum Moisture Resistant 1/2"
			Thickness	-	-
			Category	-	Gypsum Board
			Material	-	Gypsum Moisture Resistant 1/2"
			Thickness	-	-
			Category	Insulation	Insulation
			Material	Acoustic	Fiberglass Batt
			Thickness (mm)	-	64
		2.2.14 Wall_Steel stud_WA7_Roof			
			Length (ft)	7	7
			Height (ft)	3.5	3.5
			Sheathing Type	None	None
			Stud Spacing	600oc	600oc
			Stud Weight	-	Light (25Ga)
			Stud Thickness	39 x 152	38 x 152
		Envelope	Category	Gypsum Board	Gypsum Board
			Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
			Thickness	-	-
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
			Thickness	-	-
	2.3 Wood Stud				
		2.3.1 Wall_Wood stud_E4_Level ALL			
			Length (m)	880	880
			Height (m)	0.7	0.7
			Wall Type	Non leadbearing	Non leadbearing
			Sheathing Type	25 ply mulple ply cedar panel	Plywood
			Study Spacing	-	400oc
			Stud Type	Kiln dried	Kiln dried
			Stud Thickness	-	38x89
		Envelope	Category	Gypsum Board	Gypsum Board
			Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
			Thickness	-	-
			Category	Vapour Barrier	Vapour Barrier
			Material	air, vapour 7 moisture barrier	6 mil poly
			Thickness	-	-
			Category	Insulation	Insulation
			Material	R20 Mineral wool	Rockwool Batt
			Thickness (mm)	-	119
		2.3.2 Wall_Wood stud_Steel stud_WA7.3_Ground			
			Length (m)	76	76

	Height (m)	5.3	5.3
Wood Stud	Wall Type	Loadbearing	Loadbearing
	Sheathing Type	19mm wood panels	Plywood
	Study Spacing	600oc	600oc
	Stud Type	Kiln dried	Kiln dried
	Stud Thickness	-	38x89
Steel Stud	Sheathing Type	-	None
	Stud Spacing	-	600oc
	Stud Weight	-	Light (25Ga)
	Stud Thickness	-	38 x 92
Envelope	Category	Gypsum Board	Gypsum Board
	Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
	Thickness	-	-
	Category	Gypsum Board	Gypsum Board
	Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
	Thickness	-	-
2.3.3 Wall_Wood stud_Wood stud_WA7.1_Ground			
	Length (m)	6	6
	Height (m)	2.6	2.6
Wood Stud	Wall Type	Non leadbearing	Non leadbearing
	Sheathing Type	13 Plywood	Plywood
	Study Spacing	400oc	400oc
	Stud Type	Kiln dried	Kiln dried
	Stud Thickness	38 x 64	38 x 64
Wood Stud	Wall Type	Non leadbearing	Non leadbearing
	Sheathing Type	-	-
	Study Spacing	400oc	400oc
	Stud Type	Kiln dried	Kiln dried
	Stud Thickness	38 x 64	38 x 64
Envelope	Category	Gypsum Board	Gypsum Board
	Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
	Thickness (mm)	-	-
	Category	Insulation	Insulation
	Material	Acoustic	Fiberglass Batt
	Thickness (mm)	-	64
	Category	Gypsum Board	Gypsum Board
	Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
	Thickness (mm)	-	-
2.3.4 Wall_Wood stud_E3.2-W6_Level 02			
	Length (m)	43	43
	Height (m)	4.2	4.2
Wood Stud	Wall Type	Loadbearing	Loadbearing
	Sheathing Type	6mm Plywood	Plywood
	Study Spacing	300oc	400oc
	Stud Type	Kiln dried	Kiln dried
	Stud Thickness	38 x 184	38 x 184
Envelope	Category	Cladding	Cladding
	Material	90 sawn face concrete masonry	Brick - concrete
	Thickness (mm)	-	-

	Category	Insulation	Insulation
	Material	R20 Mineral wool	Rockwool Batt
	Thickness (mm)	-	119
	Category	Vapour Barrier	Vapour Barrier
	Material	air, vapour 7 moisture barrier	6 mil poly
	Thickness	-	-
	Category	Gypsum Board	Gypsum Board
	Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
	Thickness (mm)	-	-
Window Opening	Number of Windows	9	9
	Total Window Area (ft2)	6	6
	Frame Type	Fixed, Aluminum Frame	Fixed, Aluminum Frame
	Glazing Type	Low E Argon Filled Glazing	Low E Tin Argon Filled Glazing
Door Opening	Number of Doors	2	2
	Door Type	Glass Panel	Aluminum Exteror Door, 80% glazing
2.3.5 Wall_Wood stud_Wood stud_Level 02			
	Length (m)	20	20
	Height (m)	4.2	4.2
Wood Stud	Wall Type	Loadbearing	Loadbearing
	Sheathing Type	13 Plywood	Plywood
	Study Spacing	300oc	400oc
	Stud Type	Kiln dried	Kiln dried
	Stud Thickness	38 x 140	38 x 140
Wood Stud	Wall Type	Loadbearing	Loadbearing
	Sheathing Type	13 Plywood	Plywood
	Study Spacing	300oc	400oc
	Stud Type	Kiln dried	Kiln dried
	Stud Thickness	38 x 140	38 x 140
Envelope	Category	Gypsum Board	Gypsum Board
	Material	Gypsum Regular 1/2"	Gypsum Regular 1/2"
	Thickness (mm)	-	-
	Category	Insulation	Insulation
	Material	Acoustic	Fiberglass Batt
	Thickness (mm)	-	140
	Category	Gypsum Board	Gypsum Board
	Material	Gypsum Regular 1/2"	Gypsum Regular 1/2"
	Thickness (mm)	-	-
	Category	Insulation	Insulation
	Material	Acoustic	Fiberglass Batt
	Thickness (mm)	-	140
Door Opening	Number of Doors	2	2
	Door Type	Solid Wood	Solid Wood Door
2.3.6 Wall_Wood stud_W12-SW7_Level 02			
	Length (m)	19	19
	Height (m)	4.2	4.2
Wood Stud	Wall Type	Loadbearing	Loadbearing
	Sheathing Type	both sides 16mm Plywood	Plywood
	Study Spacing	300oc	400oc

	Stud Type	Kiln dried	Kiln dried
	Stud Thickness	38 x 184	38 x 184
Envelope	Category	Gypsum Board	Gypsum Board
	Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
	Thickness (mm)	-	-
	Category	Insulation	Insulation
	Material	Acoustic	Fiberglass Batt
	Thickness (mm)	-	184
	Category	Gypsum Board	Gypsum Board
	Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
	Thickness (mm)	-	-
Door Opening	Number of Doors	2	2
	Door Type	Glass Panel	Aluminum Exteror Door, 80% glazing
2.3.7 Wall_Wood stud_Steel stud_E3.1-W6_Level 02			
	Length (m)	6	6
	Height (m)	4.2	4.2
Wood Stud	Wall Type	Loadbearing	Loadbearing
	Sheathing Type	6mm Plywood	Plywood
	Study Spacing	300oc	400oc
	Stud Type	Kiln dried	Kiln dried
	Stud Thickness	38 x 184	38 x 184
Steel Stud	Sheathing Type	-	None
	Stud Spacing	-	600oc
	Stud Weight	-	Light (25Ga)
	Stud Thickness	-	38 x 92
Envelope	Category	Cladding	Cladding
	Material	90 sawn face concrete masonry	Brick - concrete
	Thickness (mm)	-	-
	Category	Vapour Barrier	Vapour Barrier
	Material	air, vapour 7 moisture barrier	6 mil poly
	Thickness	-	-
	Category	Paint	Paint
	Material	Elastomeric paint	Varnish solvent based
	Thickness (mm)	-	-
	Category	Insulation	Insulation
	Material	R20 Mineral wool	Rockwool Batt
	Thickness (mm)	-	119
	Category	Gypsum Board	Gypsum Board
	Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
	Thickness (mm)	-	-
Window Opening	Number of Windows	1	1
	Total Window Area (ft2)	0.7	0.7
	Frame Type	Fixed, Aluminum Frame	Fixed, Aluminum Frame
	Glazing Type	Low E Argon Filled Glazing	Low E Tin Argon Filled Glazing
2.3.8 Wall_Wood stud_E3.2-W6_Level 03			
	Length (m)	51	51
	Height (m)	4.2	4.2
Wood Stud	Wall Type	Loadbearing	Loadbearing

	Sheathing Type	6mm Plywood	Plywood
	Study Spacing	300oc	400oc
	Stud Type	Kiln dried	Kiln dried
	Stud Thickness	38 x 184	38 x 184
Envelope	Category	Cladding	Cladding
	Material	90 sawn face concrete masonry	Brick - concrete
	Thickness (mm)	-	-
	Category	Insulation	Insulation
	Material	R20 Mineral wool	Rockwool Batt
	Thickness (mm)	-	119
	Category	Vapour Barrier	Vapour Barrier
	Material	air, vapour 7 moisture barrier	6 mil poly
	Thickness	-	-
	Category	Gypsum Board	Gypsum Board
	Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
	Thickness (mm)	-	-
Window Opening	Number of Windows	14	14
	Total Window Area (ft2)	10.5	10.5
	Frame Type	Fixed, Aluminum Frame	Fixed, Aluminum Frame
	Glazing Type	Low E Argon Filled Glazing	Low E Tin Argon Filled Glazing
2.3.9 Wall_Wood stud_Wood stud_Level 03			
	Length (m)	20	20
	Height (m)	4.2	4.2
Wood Stud	Wall Type	Loadbearing	Loadbearing
	Sheathing Type	13 Plywood	Plywood
	Study Spacing	300oc	400oc
	Stud Type	Kiln dried	Kiln dried
	Stud Thickness	38 x 140	38 x 140
Wood Stud	Wall Type	Loadbearing	Loadbearing
	Sheathing Type	13 Plywood	Plywood
	Study Spacing	300oc	400oc
	Stud Type	Kiln dried	Kiln dried
	Stud Thickness	38 x 140	38 x 140
Envelope	Category	Gypsum Board	Gypsum Board
	Material	Gypsum Regular 1/2"	Gypsum Regular 1/2"
	Thickness (mm)	-	-
	Category	Insulation	Insulation
	Material	Acoustic	Fiberglass Batt
	Thickness (mm)	-	140
	Category	Gypsum Board	Gypsum Board
	Material	Gypsum Regular 1/2"	Gypsum Regular 1/2"
	Thickness (mm)	-	-
	Category	Insulation	Insulation
	Material	Acoustic	Fiberglass Batt
	Thickness (mm)	-	140
Door Opening	Number of Doors	2	2
	Door Type	Solid Wood	Solid Wood Door
2.3.10 Wall_Wood stud_W12-SW7_Level 03			
	Length (m)	19	19

			Height (m)	4.2	4.2
		Wood Stud	Wall Type	Loadbearing	Loadbearing
			Sheathing Type	both sides 16mm Plywood	Plywood
			Study Spacing	300oc	400oc
			Stud Type	Kiln dried	Kiln dried
			Stud Thickness	38 x 184	38 x 184
		Envelope	Category	Gypsum Board	Gypsum Board
			Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
			Thickness (mm)	-	-
			Category	Insulation	Insulation
			Material	Acoustic	Fiberglass Batt
			Thickness (mm)	-	184
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
			Thickness (mm)	-	-
		Door Opening	Number of Doors	4	4
			Door Type	Glass Panel	Aluminum Exteror Door, 80% glazing
		2.3.11 Wall_Wood stud_Steel stud_E3.1-W6_Level 03			
			Length (m)	6	6
			Height (m)	4.2	4.2
		Wood Stud	Wall Type	Loadbearing	Loadbearing
			Sheathing Type	6mm Plywood	Plywood
			Study Spacing	300oc	400oc
			Stud Type	Kiln dried	Kiln dried
			Stud Thickness	38 x 184	38 x 184
		Steel Stud	Sheathing Type	-	None
			Stud Spacing	-	600oc
			Stud Weight	-	Light (25Ga)
			Stud Thickness	-	38 x 92
		Envelope	Category	Cladding	Cladding
			Material	90 sawn face concrete masonry	Brick - concrete
			Thickness (mm)	-	-
			Category	Vapour Barrier	Vapour Barrier
			Material	air, vapour 7 moisture barrier	6 mil poly
			Thickness	-	-
			Category	Paint	Paint
			Material	Elastomeric paint	Varnish solvent based
			Thickness (mm)	-	-
			Category	Insulation	Insulation
			Material	R20 Mineral wool	Rockwool Batt
			Thickness (mm)	-	119
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
			Thickness (mm)	-	-
		Window Opening	Number of Windows	1	1
			Total Window Area (ft2)	0.7	0.7
			Frame Type	Fixed, Aluminum Frame	Fixed, Aluminum Frame
			Glazing Type	Low E Argon	Low E Tin Argon Filled

		Filled Glazing	Glazing
2.3.12 Wall_Wood stud_WA7.1-SW8_Level 03			
Wood Stud	Length (m)	10	10
	Height (m)	4.2	4.2
	Wall Type	Non leadbearing	Non leadbearing
	Sheathing Type	13 Plywood	Plywood
	Study Spacing	300oc	400oc
	Stud Type	Kiln dried	Kiln dried
	Stud Thickness	38 x 184	38 x 184
Envelope	Category	Gypsum Board	Gypsum Board
	Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
	Thickness (mm)	-	-
	Category	Insulation	Insulation
	Material	Acoustic	Fiberglass Batt
	Thickness (mm)	-	64
	Category	Gypsum Board	Gypsum Board
	Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
	Thickness (mm)	-	-
2.3.13 Wall_Wood stud_E3.2-W6_Level 04			
Wood Stud	Length (m)	51	51
	Height (m)	4.2	4.2
	Wall Type	Loadbearing	Loadbearing
	Sheathing Type	6mm Plywood	Plywood
	Study Spacing	300oc	400oc
	Stud Type	Kiln dried	Kiln dried
	Stud Thickness	38 x 184	38 x 184
Envelope	Category	Cladding	Cladding
	Material	90 sawn face concrete masonry	Brick - concrete
	Thickness (mm)	-	-
	Category	Insulation	Insulation
	Material	R20 Mineral wool	Rockwool Batt
	Thickness (mm)	-	119
	Category	Vapour Barrier	Vapour Barrier
	Material	air, vapour 7 moisture barrier	6 mil poly
	Thickness	-	-
	Category	Gypsum Board	Gypsum Board
	Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
	Thickness (mm)	-	-
Window Opening	Number of Windows	14	14
	Total Window Area (ft2)	10.5	10.5
	Frame Type	Fixed, Aluminum Frame	Fixed, Aluminum Frame
	Glazing Type	Low E Argon Filled Glazing	Low E Tin Argon Filled Glazing
2.3.14 Wall_Wood stud_Wood stud_Level 04			
Wood Stud	Length (m)	20	20
	Height (m)	4.2	4.2
	Wall Type	Loadbearing	Loadbearing
	Sheathing Type	13 Plywood	Plywood
	Study Spacing	300oc	400oc

				Stud Type	Kiln dried	Kiln dried
				Stud Thickness	38 x 140	38 x 140
			Wood Stud	Wall Type	Loadbearing	Loadbearing
				Sheathing Type	13 Plywood	Plywood
				Study Spacing	300oc	400oc
				Stud Type	Kiln dried	Kiln dried
				Stud Thickness	38 x 140	38 x 140
			Envelope	Category	Gypsum Board	Gypsum Board
				Material	Gypsum Regular 1/2"	Gypsum Regular 1/2"
				Thickness (mm)	-	-
				Category	Insulation	Insulation
				Material	Acoustic	Fiberglass Batt
				Thickness (mm)	-	140
				Category	Gypsum Board	Gypsum Board
				Material	Gypsum Regular 1/2"	Gypsum Regular 1/2"
				Thickness (mm)	-	-
				Category	Insulation	Insulation
				Material	Acoustic	Fiberglass Batt
				Thickness (mm)	-	140
			Door Opening	Number of Doors	2	2
				Door Type	Solid Wood	Solid Wood Door
		2.3.15 Wall_Wood stud_W12-SW7_Level 04				
				Length (m)	19	19
				Height (m)	4.2	4.2
			Wood Stud	Wall Type	Loadbearing	Loadbearing
				Sheathing Type	both sides 16mm Plywood	Plywood
				Study Spacing	300oc	400oc
				Stud Type	Kiln dried	Kiln dried
				Stud Thickness	38 x 184	38 x 184
			Envelope	Category	Gypsum Board	Gypsum Board
				Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
				Thickness (mm)	-	-
				Category	Insulation	Insulation
				Material	Acoustic	Fiberglass Batt
				Thickness (mm)	-	184
				Category	Gypsum Board	Gypsum Board
				Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
				Thickness (mm)	-	-
			Door Opening	Number of Doors	4	4
				Door Type	Glass Panel	Aluminum Exteror Door, 80% glazing
		2.3.16 Wall_Wood stud_WA7.1-SW8_Level 04				
				Length (m)	10	10
				Height (m)	4.2	4.2
			Wood Stud	Wall Type	Non leadbearing	Non leadbearing
				Sheathing Type	13 Plywood	Plywood
				Study Spacing	300oc	400oc
				Stud Type	Kiln dried	Kiln dried
				Stud Thickness	38 x 184	38 x 184
			Envelope	Category	Gypsum Board	Gypsum Board

				Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
				Thickness (mm)	-	-
				Category	Insulation	Insulation
				Material	Acoustic	Fiberglass Batt
				Thickness (mm)	-	64
				Category	Gypsum Board	Gypsum Board
				Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
				Thickness (mm)	-	-
		2.3.17 Wall_Wood stud_Steel stud_E3.1-W6_Level 04				
				Length (m)	6	6
				Height (m)	4.2	4.2
			Wood Stud	Wall Type	Loadbearing	Loadbearing
				Sheathing Type	6mm Plywood	Plywood
				Study Spacing	300oc	400oc
				Stud Type	Kiln dried	Kiln dried
				Stud Thickness	38 x 184	38 x 184
			Steel Stud	Sheathing Type	-	None
				Stud Spacing	-	600oc
				Stud Weight	-	Light (25Ga)
				Stud Thickness	-	38 x 92
			Envelope	Category	Cladding	Cladding
				Material	90 sawn face concrete masonry	Brick - concrete
				Thickness (mm)	-	-
				Category	Vapour Barrier	Vapour Barrier
				Material	air, vapour 7 moisture barrier	6 mil poly
				Thickness	-	-
				Category	Paint	Paint
				Material	Elastomeric paint	Varnish solvent based
				Thickness (mm)	-	-
				Category	Insulation	Insulation
				Material	R20 Mineral wool	Rockwool Batt
				Thickness (mm)	-	119
				Category	Gypsum Board	Gypsum Board
				Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
				Thickness (mm)	-	-
			Window Opening	Number of Windows	1	1
				Total Window Area (ft2)	0.7	0.7
				Frame Type	Fixed, Aluminum Frame	Fixed, Aluminum Frame
				Glazing Type	Low E Argon Filled Glazing	Low E Tin Argon Filled Glazing
		2.3.18 Wall_Wood stud_E3.2-SW8_Roof				
				Length (m)	40	40
				Height (m)	3.5	3.5
			Wood Stud	Wall Type	Loadbearing	Loadbearing
				Sheathing Type	6mm Plywood	Plywood
				Study Spacing	300oc	400oc
				Stud Type	Kiln dried	Kiln dried
				Stud Thickness	38 x 184	38 x 184
			Envelope	Category	Cladding	Cladding

	Material	90 sawn face concrete masonry	Brick - concrete
	Thickness (mm)	-	-
	Category	Insulation	Insulation
	Material	R20 Mineral wool	Rockwool Batt
	Thickness (mm)	-	119
	Category	Vapour Barrier	Vapour Barrier
	Material	air, vapour 7 moisture barrier	6 mil poly
	Thickness	-	-
	Category	Gypsum Board	Gypsum Board
	Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
	Thickness (mm)	-	-
Window Opening	Number of Windows	8	8
	Total Window Area (ft2)	5.2	5.2
	Frame Type	Fixed, Aluminum Frame	Fixed, Aluminum Frame
	Glazing Type	Low E Argon Filled Glazing	Low E Tin Argon Filled Glazing
Door Opening	Number of Doors	4	4
	Door Type	Hollow Steel	Steel Exterior Door
2.3.19 Wall_Wood stud_E11_Roof			
	Length (m)	26	26
	Height (m)	2	2
Wood Stud	Wall Type	Non loadbearing	Non loadbearing
	Sheathing Type	13mm Plywood	Plywood
	Study Spacing	-	400oc
	Stud Type	Kiln dried	Kiln dried
	Stud Thickness	38 x 140	38 x 140
Envelope	Category	Insulation	Insulation
	Material	R20 Mineral wool	Rockwool Batt
	Thickness (mm)	-	119
	Category	Vapour Barrier	Vapour Barrier
	Material	vapour permeable membrane	3 mil poly
	Thickness	-	-
	Category	15 ext grade sheathing	-
	Material	-	-
	Thickness (mm)	-	-
Door Opening	Number of Doors	6	6
	Door Type	Hollow Steel	Steel Exterior Door
2.3.20 Wall_Wood stud_E3.2-W6_Roof			
	Length (m)	22	22
	Height (m)	3.5	3.5
Wood Stud	Wall Type	Loadbearing	Loadbearing
	Sheathing Type	Plywood	Plywood
	Study Spacing	300oc	400oc
	Stud Type	Kiln dried	Kiln dried
	Stud Thickness	38 x 184	38 x 184
Envelope	Category	Cladding	Cladding
	Material	90 sawn face concrete masonry	Brick - concrete
	Thickness (mm)	-	-
	Category	Insulation	Insulation

			Material	R20 Mineral wool	Rockwool Batt
			Thickness (mm)	-	119
			Category	Vapour Barrier	Vapour Barrier
			Material	air, vapour 7 moisture barrier	6 mil poly
			Thickness	-	-
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
			Thickness (mm)	-	-
		Window Opening	Number of Windows	1.3	1.3
			Total Window Area (ft2)	2	2
			Frame Type	Fixed, Aluminum Frame	Fixed, Aluminum Frame
			Glazing Type	Low E Argon Filled Glazing	Low E Tin Argon Filled Glazing
	2.4 Curtain Wall				
		2.4.1 Wall_Curtain wall_E7.2_Ground			
			Length (m)	93	93
			Height (m)	5.3	5.3
			Percent Viewable Glazing	-	-
			Percent Spandrel Panel	-	-
			Thickness of Insulation (mm)	-	-
			Spandrel Type (Metal/Glass)	Glass	Glass
		Door Opening	Number of Doors	10	10
			Door Type	Glass Panel Pair	Aluminum Exterior Door, 80% glazing
		2.4.2 Wall_Curtain wall_W11_Ground			
			Length (m)	10	10
			Height (m)	5.3	5.3
			Percent Viewable Glazing	-	-
			Percent Spandrel Panel	-	-
			Thickness of Insulation (mm)	-	-
			Spandrel Type (Metal/Glass)	Glass	Glass
		Door Opening	Number of Doors	2	2
			Door Type	Solid Wood	Solid Wood Door
		2.4.3 Wall_Curtain wall_E5.1/5.2/6/7_Level 02			
			Length (m)	155	155
			Height (m)	4.2	4.2
			Percent Viewable Glazing	82%	82%
			Percent Spandrel Panel	18%	18%
			Thickness of Insulation (mm)	-	25mm
			Spandrel Type (Metal/Glass)	Glass	Glass
		Door Opening	Number of Doors	2	2
			Door Type	-	Aluminum Exterior Door, 80% glazing
		2.4.4 Wall_Curtain wall_W11_Level 02			
			Length (m)	10	10
			Height (m)	4.2	4.2

	Percent Viewable Glazing	-	-
	Percent Spandrel Panel	-	-
	Thickness of Insulation (mm)	-	-
	Spandrel Type (Metal/Glass)	Glass	Glass
Door Opening	Number of Doors	5	5
	Door Type	Solid Wood	Solid Wood Door
2.4.5 Wall_Curtain wall_E5.1/5.2/6/7_Level 03			
	Length (m)	155	155
	Height (m)	4.2	4.2
	Percent Viewable Glazing	82%	82%
	Percent Spandrel Panel	18%	18%
	Thickness of Insulation (mm)	-	25mm
	Spandrel Type (Metal/Glass)	Glass	Glass
2.4.6 Wall_Curtain wall_W11_Level 03			
	Length (m)	10	10
	Height (m)	4.2	4.2
	Percent Viewable Glazing	-	-
	Percent Spandrel Panel	-	-
	Thickness of Insulation (mm)	-	-
	Spandrel Type (Metal/Glass)	Glass	Glass
Door Opening	Number of Doors	5	5
	Door Type	Solid Wood	Solid Wood Door
2.4.7 Wall_Curtain wall_E5.1/5.2/6/7_Level 04			
	Length (m)	155	155
	Height (m)	4.2	4.2
	Percent Viewable Glazing	82%	82%
	Percent Spandrel Panel	18%	18%
	Thickness of Insulation (mm)	-	25mm
	Spandrel Type (Metal/Glass)	Glass	Glass
2.4.8 Wall_Curtain wall_W11_Level 04			
	Length (m)	10	10
	Height (m)	4.2	4.2
	Percent Viewable Glazing	-	-
	Percent Spandrel Panel	-	-
	Thickness of Insulation (mm)	-	-
	Spandrel Type (Metal/Glass)	Glass	Glass
Door Opening	Number of Doors	5	5
	Door Type	Solid Wood	Solid Wood Door
2.4.9 Wall_Curtain wall_E5.1/2_Roof			
	Length (m)	46	46
	Height (m)	1.6	1.6
	Percent Viewable	-	-

			Glazing		
			Percent Spandrel Panel	-	-
			Thickness of Insulation (mm)	-	-
			Spandrel Type (Metal/Glass)	Glass	Glass
3 Columns and Beams					
	3.1 Concrete Columns				
		3.1.1 Column_Concrete_C1 & C4_Beam_N/A_Basement			
			Number of Beams	0	0
			Number of Columns	5	5
			Floor to floor height (ft)	11.5	11.5
			Bay sizes (ft)	24.75	24.75
			Supported span (ft)	22.65	22.65
			Live load (psf)	100	100
		3.1.1.1 Column_Concrete_C2_Beam_N/A_Basement			
			Number of Beams	0	0
			Number of Columns	4	4
			Floor to floor height (ft)	13.75	13.75
			Bay sizes (ft)	45.25	45.25
			Supported span (ft)	20	20
			Live load (psf)	100	100
		3.1.2 Column_Concrete_C2_Beam_N/A_GroundLevel			
			Number of Beams	0	0
			Number of Columns	2	2
			Floor to floor height (ft)	13	13
			Bay sizes (ft)	45.25	45.25
			Supported span (ft)	20	20
			Live load (psf)	100	100
		3.1.3 Column_N/A_Beam_Glulam_GroundLevel_Hor (Auditorium)			
			Number of Beams	2	2
			Number of Columns	0	0
			Floor to floor height (ft)	13	13
			Bay sizes (ft)	71	71
			Supported span (ft)	11	11
			Live load (psf)	100	100
	3.2 Wooden Columns & Beams				
		3.2.1 Column_Beam_Glulam_GroundLevel_Vert (Wings)			
			Number of Beams	23	23
			Number of Columns	45	45
			Floor to floor height (ft)	13	13

				Bay sizes (ft)	32	32
				Supported span (ft)	10	10
				Live load (psf)	100	100
			3.2.1.1 Column_Beam_Glulam_GroundLevel_Horizontal (Wings)			
				Number of Beams	37	37
				Number of Columns	40	40
				Floor to floor height (ft)	13	13
				Bay sizes (ft)	10	10
				Supported span (ft)	8	8
				Live load (psf)	100	100
			3.2.1.2 Column_N/A_Beam_Glulam_GroundLevel_Vert (Auditorium)			
				Number of Beams	7	7
				Number of Columns	2	2
				Floor to floor height (ft)	13	13
				Bay sizes (ft)	45.25	45.25
				Supported span (ft)	10	10
				Live load (psf)	100	100
			3.2.1.3 Column_Beam_Glulam_GroundLevel_Atrium			
				Number of Beams	1	1
				Number of Columns	2	2
				Floor to floor height (ft)	13	13
				Bay sizes (ft)	45	45
				Supported span (ft)	4	4
				Live load (psf)	100	100
			3.2.1.4 Column_Beam_Glulam_GroundLevel_Connecting lobby_Hor			
				Number of Beams	6	6
				Number of Columns	6	6
				Floor to floor height (ft)	13	13
				Bay sizes (ft)	18.85	18.85
				Supported span (ft)	10	10
				Live load (psf)	100	100
			3.2.2.1 Column_Glulam_Beam_N/A_GroundLevel_Stairs			
				Number of Beams	0	0
				Number of Columns	4	4
				Floor to floor height (ft)	13	13
				Bay sizes (ft)	32	32
				Supported span (ft)	10	10
				Live load (psf)	100	100

		3.2.2.2 Column_Glulam_Beam_N/A_GroundLevel_Elev shaft			
			Number of Beams	0	0
			Number of Columns	4	4
			Floor to floor height (ft)	13	13
			Bay sizes (ft)	9	9
			Supported span (ft)	5.25	5.25
			Live load (psf)	100	100
		3.2.2.3 Column_Beam_Glulam_Level2_Vert (Wings)			
			Number of Beams	23	23
			Number of Columns	45	45
			Floor to floor height (ft)	13	13
			Bay sizes (ft)	32	32
			Supported span (ft)	10	10
			Live load (psf)	100	100
		3.2.2.4 Column_Beam_Glulam_Level2_Horizontal (Wings)			
			Number of Beams	37	37
			Number of Columns	40	40
			Floor to floor height (ft)	13	13
			Bay sizes (ft)	10	10
			Supported span (ft)	8	8
			Live load (psf)	100	100
		3.2.2.5 Column_Beam_Glulam_Level2_Atrium			
			Number of Beams	1	1
			Number of Columns	2	2
			Floor to floor height (ft)	13	13
			Bay sizes (ft)	45	45
			Supported span (ft)	4	4
			Live load (psf)	100	100
		3.2.2.5 Column_Beam_Glulam_Level2_Connecting lobby_Hor			
			Number of Beams	6	6
			Number of Columns	6	6
			Floor to floor height (ft)	13	13
			Bay sizes (ft)	18.85	18.85
			Supported span (ft)	10	10
			Live load (psf)	100	100
		3.2.2.1 Column_Glulam_Beam_N/A_Level2_Stairs			
			Number of Beams	0	0
			Number of Columns	4	4
			Floor to floor height (ft)	13	13
			Bay sizes (ft)	32	32

	Supported span (ft)	10	10
	Live load (psf)	100	100
3.2.2.2 Column_Glulam_Beam_N/A_Level2_Elev shaft			
	Number of Beams	0	0
	Number of Columns	4	4
	Floor to floor height (ft)	13	13
	Bay sizes (ft)	9	9
	Supported span (ft)	5.25	5.25
	Live load (psf)	100	100
3.2.2.3 Column_Beam_Glulam_Level3_Vert (Wings)			
	Number of Beams	23	23
	Number of Columns	45	45
	Floor to floor height (ft)	13	13
	Bay sizes (ft)	32	32
	Supported span (ft)	10	10
	Live load (psf)	100	100
3.2.2.4 Column_Beam_Glulam_Level3_Horizontal (Wings)			
	Number of Beams	37	37
	Number of Columns	40	40
	Floor to floor height (ft)	13	13
	Bay sizes (ft)	10	10
	Supported span (ft)	8	8
	Live load (psf)	100	100
3.2.2.5 Column_Beam_Glulam_Level3_Atrium			
	Number of Beams	1	1
	Number of Columns	2	2
	Floor to floor height (ft)	13	13
	Bay sizes (ft)	45	45
	Supported span (ft)	4	4
	Live load (psf)	100	100
3.2.2.5 Column_Beam_Glulam_Level3_Connecting lobby_Hor			
	Number of Beams	6	6
	Number of Columns	6	6
	Floor to floor height (ft)	13	13
	Bay sizes (ft)	18.85	18.85
	Supported span (ft)	10	10
	Live load (psf)	100	100
3.2.2.1 Column_Glulam_Beam_N/A_Level3_Stairs			
	Number of Beams	0	0
	Number of Columns	4	4
	Floor to floor height (ft)	13	13

			Bay sizes (ft)	32	32
			Supported span (ft)	10	10
			Live load (psf)	100	100
		3.2.2.2 Column_Glulam_Beam_N/A_Level3_Elev shaft			
			Number of Beams	0	0
			Number of Columns	4	4
			Floor to floor height (ft)	13	13
			Bay sizes (ft)	9	9
			Supported span (ft)	5.25	5.25
			Live load (psf)	100	100
		3.2.2.3 Column_Beam_Glulam_Roof_Vert (Wings)			
			Number of Beams	23	23
			Number of Columns	45	45
			Floor to floor height (ft)	13	13
			Bay sizes (ft)	32	32
			Supported span (ft)	10	10
			Live load (psf)	100	100
		3.2.2.4 Column_Beam_Glulam_Roof_Horizontal (Wings)			
			Number of Beams	37	37
			Number of Columns	40	40
			Floor to floor height (ft)	13	13
			Bay sizes (ft)	10	10
			Supported span (ft)	8	8
			Live load (psf)	100	100
		3.2.2.1 Column_Glulam_Beam_N/A_Roof_Stairs			
			Number of Beams	0	0
			Number of Columns	4	4
			Floor to floor height (ft)	13	13
			Bay sizes (ft)	32	32
			Supported span (ft)	10	10
			Live load (psf)	100	100
		3.2.2.2 Column_Glulam_Beam_N/A_Roof_Elev shaft			
			Number of Beams	0	0
			Number of Columns	4	4
			Floor to floor height (ft)	13	13
			Bay sizes (ft)	9	9
			Supported span (ft)	5.25	5.25
			Live load (psf)	100	100
	3.3 Steel Beams				
		3.3.1 Column_N/A_Beam_HSS_Penthouse_Hor			
			Number of Beams	12	12
			Number of Columns	24	24

			Floor to floor height (ft)	5	5
			Bay sizes (ft)	11.75	11.75
			Supported span (ft)	5	5
			Live load (psf)	40	40
		3.3.2 Column_N/A_Beam_HSS_Penthouse_Vert			
			Number of Beams	26	26
			Number of Columns	24	24
			Floor to floor height (ft)	5	5
			Bay sizes (ft)	5	5
			Supported span (ft)	5	5
			Live load (psf)	40	40
3.4 Extra Base Material					
	3.4.1 Glulam Beams				
		Column_N/A_ Beams_ Glulam_Ground Level_38 x 286			
			Volume of Glulam lumber m^3		28.606
		Column_N/A_ Beams_ Glulam_Level 2_38 x 286			
			Volume of Glulam lumber m^3		18.905
		Column_N/A_ Beams_ Glulam_Level 3_38 x 286			
			Volume of Glulam lumber m^3		16.903
		Column_N/A_ Beams_ Glulam_Level 3_38 x 286			
			Volume of Glulam lumber m^3		25.892
		Column_N/A_ Beams_ Glulam_Penthouse_38 x 286			
			Volume of Glulam lumber m^3		5.317
	3.4.2 Stairs				
		Stairs_ Glulam Wooden Stingers_ all floors	Volume of Glulam lumber m^3		40.74
		Stairs_Concrete_GroundLevel_Entrance	Volume of Concrete m^3		1.717
			Concrete (psi)	4350	4000
			Concrete flyash %	30	25
			Rebar	20M	20M
	3.4.3 Hollow Structural steel (HSS)				
		HSS 102x76x8.5 _ Penthouse_Skylight	Volume of Steel Tonnes		87.82

	3.4.3 Skylight Glazing				
		Skylight glazing	Area m^2		149.57
4. Floor					
	Concrete Slab on Grade				
		Floor_F10_SLAB-ON-GRADE			
			Area (m^2)	1179	1179
			Span (m)	9.8	12.2
			Width (m)	120.3061224	145.15
			Live load (kPa)	4.8	4.8
			Category	Concrete	Concrete
			Material	Concrete slab	Concrete slab
			Thickness (mm)	150.00	100.00
			Concrete flyash %	0.3	0.25
			Concrete (mPa)	30	30
			Category	Vapour barrier	Vapour barrier
			Material	-	Poly
			Thickness (mm)	-	6.00
		Floor_F11_SLAB-ON-GRADE-RAISED-FLOOR			
			Area (m^2)	260.8	260.8
			Span (m)	9.8	12.2
			Width (m)	26.6122449	32.1
			Live load (kPa)	4.8	4.8
			Category	Concrete	Concrete
			Material	Concrete slab	Concrete slab
			Thickness (mm)	150	100
			Concrete flyash %	0.3	0.25
			Concrete (mPa)	30	30
			Category	Vapour barrier	Vapour barrier
			Material	-	Poly
			Thickness (mm)	-	6
	SUSPENDED CONCRETE SLAB				
		Floor_F20_SUSPENDED-CONCRETE-SLAB			
			Area (m^2)	14.6	14.6
			Span (m)	1.75	1.75
			Width (m)	8.342857143	8.342857143
			Live load (kPa)	4.8	4.8
			Category	Concrete	Concrete
			Material 1	Concrete slab	Concrete slab
			Thickness (mm)	200	200
			Concrete flyash %	0.3	0.25
			Concrete (mPa)	30	30
		Floor_F21_SUSPENDED-CONCRETE-SLAB-EPOXY			
			Area (m^2)	33.3	33.3

			Span (m)	3.5	3.5
			Width (m)	9.514285714	9.514285714
			Live load (kPa)	4.8	4.8
			Category	Concrete	Concrete
			Material	Concrete slab	Concrete slab
			Thickness (mm)	300	300
			Concrete flyash %	0.3	0.25
			Concrete (mPa)	30	30
		Floor_F23_SUSPENDED-CONCRETE-SLAB-TERRAZZO			
			Area (m^2)	580.6	580.6
			Span (m)	9.8	9.8
			Width (m)	59.24489796	59.24489796
			Live load (kPa)	4.8	4.8
			Category	Concrete	Concrete
			Material	Concrete slab	Concrete slab
			Thickness (mm)	250	250.00
			Concrete flyash %	0.3	0.25
			Concrete (mPa)	30	30
		Floor_F30_SUSPENDED-CONCRETE-SLAB-RAISED-TECRETE			
			Area (m^2)	435.5	435.5
			Span (m)	9.8	9.8
			Width (m)	44.43877551	44.43877551
			Live load (kPa)	4.8	4.80
			Category	Concrete	Concrete
			Material	Concrete slab	Concrete slab
			Thickness (mm)	250	250
			Concrete flyash %	0.3	Average
			Concrete (mPa)	30	30
	LAMINATED WOOD				
		Floor_F40_LAMINATED-WOOD-RAISED-TECRETE			
			Area (m^2)	1778.3	
			Span (m)	9.8	
			Width (m)	181.4591837	
			Live load (kPa)	4.8	
			Category	-	
			Material	Laminated wood	
			Thickness (mm)	89	
			Decking	Plywood	
			Thickness (mm)	16	
			Category	Underlay	Steel roof system
			Material	Sheet metal	Galvanized sheet
			Thickness (mm)	-	12 GA
		Floor_F41_LAMINATED-WOOD-RAISED-TECRETE-SLOPED-TILE			
			Area (m^2)	45.9	
			Span (m)	9.8	

			Width (m)	4.683673469	
			Live load (kPa)	4.8	
			Category	-	
			Material	Laminated wood	
			Thickness (mm)	89	
			Decking	Plywood	
			Thickness (mm)	16	
			Category	Underlay	Steel roof system
			Material	Sheet metal	Galvanized sheet
			Thickness (mm)	-	12 GA
			Category	-	
			Material	Concrete topping	
			Thickness (mm)	25	
		Floor_F42_LAMINATED-WOOD-RAISED-TECRETE-SOFFIT			
			Area (m^2)	288.2	
			Span (m)	9.8	
			Width (m)	29.40816327	
			Live load (kPa)	4.8	
			Category	-	
			Material	Laminated wood	
			Thickness (mm)	89	
			Decking	Plywood	
			Thickness (mm)	16	
			Category	Underlay	Steel roof system
			Material	Sheet metal	Galvanized sheet
			Thickness (mm)	-	12 GA
			Category	Vapour barrier	Vapour barrier
			Material	-	Poly
			Thickness (mm)	-	6
			Category	Insulation	Insulation
			Material	Insulation	Polystyrene Expanded
			Thickness (mm)	150	150
		Floor_F43_LAMINATED-WOOD-RAISED-TECRETE-SLOPED-TILE-SOFFIT			
			Area (m^2)	22.40	
			Span (m)	9.80	
			Width (m)	2.285714286	
			Live load (kPa)	4.8	
			Category	-	
			Material	Laminated wood	
			Thickness (mm)	89	
			Decking	Plywood	
			Thickness (mm)	16	
			Category	Underlay	Steel roof system
			Material	Sheet metal	Galvanized sheet
			Thickness (mm)	-	12 GA
			Category	-	
			Material	Concrete topping	
			Thickness (mm)	25	
			Category	Vapour barrier	Vapour barrier

			Material Thickness (mm)	- -	Poly 6
			Category Material Thickness (mm)	Insulation Insulation 150	Insulation Polystyrene Expanded 150
		Floor_F50_LAMINATED-WOOD-CONCRETE-TOPPING			
			Area (m²) Span (m) Width (m) Live load (kPa) Category Material Thickness (mm) Decking Thickness (mm)	141.9 9.8 14.47959184 4.8 - Laminated wood 184 Plywood 16	
			Category Material Thickness (mm)	- Concrete topping 50	
		Floor_F51_LAMINATED-WOOD-CONCRETE-TOPPING-SOFFIT			
			Area (m²) Span (m) Width (m) Live load (kPa) Category Material Thickness (mm) Decking Thickness (mm)	120 9.8 12.24489796 4.8 - Laminated wood 184 Plywood 16	
			Category Material Thickness (mm)	- Concrete topping 50	
			Category Material Thickness (mm)	Vapour barrier - -	Vapour barrier Poly 6.00
			Category Material Thickness (mm)	Insulation Insulation 150	Insulation Polystyrene Expanded 150
		Floor_F52_LAMINATED-WOOD-CONCRETE-TOPPING-GWB-CEILING			
			Area (m²) Span (m) Width (m) Live load (kPa) Category Material Thickness (mm) Decking Thickness (mm)	85.4 9.8 8.714285714 4.8 - Laminated wood 184 Plywood 16	
			Category	-	

			Material	Concrete topping	
			Thickness (mm)	50	
			Category	GWB	Gypsum Board
			Material	Insulation	Gypsum Board
			Thickness (mm)	13	1/2"
	WOOD JOIST				
		Floor_F53_WOOD-FLOOR-JOISTS			
			Area (m^2)	89.25	89.25
			Span (m)	9.8	9.8
			Width (m)	9.107142857	3.65
					3.65
					1.8
			Live load (kPa)	4.8	4.80
			Category	Wood joist	Wood joist
			Material	Wood joist	Wood joist
			Thickness (mm)	184	-
			Decking	Plywood	Plywood
			Thickness (mm)	19	19
			Category	GWB	Gypsum Board
			Material	Insulation	Gypsum Board
			Thickness (mm)	13	1/2"
5 Roof					
	Green roof				
		Roof_R1_LAMINATED-WOOD-GREEN-ROOF			
			Area (m^2)	372.5	
			Span (m)	9.8	
			Width (m)	38.01020408	
			Live load (kPa)	4.8	
			Category	-	
			Material	Laminated wood	
			Thickness (mm)	184	
			Decking	Plywood	
			Thickness (mm)	16	
			Category	Vapour retarder	Vapour retarder
			Material	-	Poly
			Thickness (mm)	-	6
			Category	Insulation	Insulation
			Material	Insulation	EPDM white
			Thickness (mm)	100	100
			Category	Roof envelope	Roof envelope
			Material	TPO	PVC membrane
			Thickness (mm)	60	-
	LAMINATED WOOD				
		Roof_R2_LAMINATED-WOOD-PAVING-STONE			
			Area (m^2)	83.4	
			Span (m)	9.8	
			Width (m)	8.510204082	
			Live load (kPa)	4.8	
			Category	-	

			Material	Laminated wood	
			Thickness (mm)	184	
			Decking	Plywood	
			Thickness (mm)	19	
			Category	Vapour retarder	Vapour retarder
			Material	-	Poly
			Thickness (mm)	-	6
			Category	Insulation	Insulation
			Material	Insulation	Polystyrene Expanded
			Thickness (mm)	100	100
			Category	Roof envelope	Roof envelope
			Material	TPO	EPDM white
			Thickness (mil)	60	-
			Category	Roof envelope	Roof envelope
			Material	Concrete pavers	Concrete tile
			Thickness (mm)	50	-
		Roof_R3_LAMINATED-WOOD-SLOPED-INSULATION			
			Area (m^2)	996.4	
			Span (m)	9.8	
			Width (m)	101.6734694	
			Live load (kPa)	4.8	
			Category	-	
			Material	Laminated wood	
			Thickness (mm)	89.00	
			Decking	Plywood	
			Thickness (mm)	19	
			Category	Vapour retarder	Vapour retarder
			Material	-	Poly
			Thickness (mm)	-	6
			Category	Insulation	Insulation
			Material	Insulation	Polystyrene Expanded
			Thickness (mm)	100	100
			Category	Roof envelope	Roof envelope
			Material	TPO	EPDM white
			Thickness (mil)	60	-
	WOOD JOIST				
		Roof_R4_WOOD-JOISTS			
			Area (m^2)	34.6	34.6
			Span (m)	9.8	9.8
			Width (m)	3.530612245	3.530612245
			Live load (kPa)	4.8	4.8
			Category	Wood joist	Wood joist
			Material	Wood joist	Wood joist
			Thickness (mm)	184	-
			Decking	Plywood	Plywood
			Thickness (mm)	16	15
			Category	Vapour retarder	Vapour retarder
			Material	-	Poly
			Thickness (mm)	-	6
			Category	Insulation	Insulation

			Material	Insulation	Polystyrene Expanded
			Thickness (mm)	100	100
			Category	Roof envelope	Roof envelope
			Material	TPO	EPDM white
			Thickness (mil)	60	-
6 Extra basic materials					
	RAISED FLOOR				
		EBM_RAISED-FLOOR_TEC-CRETE			
			Volume (m^3)	82.1019	82.1
			Area (m^2)	2831.1	-
			Span (m)	9.8	-
			Width (m)	288.8877551	-
			Category	Concrete	Concrete
			Material	Tec-crete	Concrete/Masonary blocks
			Thickness (mm)	29	-
			Panel size (mm)	625	40000
			Total panels	4529.76	71
		EBM_RAISED-FLOOR_PEDESTAL			
			Volume (m^3)	2.827750923	-
			Density (kg/m^3)	8000	-
			Tonnes	22.62200738	23
			Category	Steel	Steel
			Material	Steel	HSS
			Count	4802.973967	-
			Pedestal volume (m^3)	0.00058875	-
			Pedestal area (m^2)	0.0019625	-
			Pedestal height (m)	0.3	-
	LAMINATED WOOD				
		EBM_LAMINATED-WOOD			
			Category	Wood	Wood
			Material	Laminated wood	Softwood lumber kiln
			Volume (m^3)	342.58	342.6
			Thickness (mm)	-	-
		EBM_CONCRETE-TOPPING			
			Category	Concrete	Concrete
			Material	Concrete topping	Concrete topping
			Volume (m^3)	19.0725	19.1
			Concrete flyash %	0.3	Average
			Concrete (mPa)	30	30

9. Appendix B– Impact Estimator Assumption Document

<table>
<tr><th>Assembly Group</th><th>Assembly Type</th><th>Assembly Name</th><th>Specific Assumptions</th></tr>
<tr><td rowspan="6">1 Foundation</td><td colspan="3">The Impact Estimator, SOG inputs are limited to being either a 4" or 8" thickness. Some of the mechanical room padding is considered in Sog as it is on top of the basement SoG slab, the actual SOG thicknesses for the CIRS building were not exactly 4" or 8" thick but 6", the areas measured in Autodesk QTO required calculations to adjust the areas to accommodate this limitation.
The Impact Estimator limits the Concrete strength to 3000, 4000 & 9000psi, we had to limit the actual strength of concrete for footings as per the Athena input i.e. 4000psi. Some of the mat footings were missing depth, e.g. MAT 1 & 2, drawing S201. Typical mat foundation thickness was considered from other mat foundations.</td></tr>
<tr><td colspan="3">1.1 Concrete Slab-on-Grade</td></tr>
<tr><td rowspan="3"></td><td>1.2.1 SoG_Mech Mat_150mm</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)]
= 90.42 ft</td></tr>
<tr><td>1.1.2 SoG_Mat_1_150mm_Auditorium</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)]
= 13.24 ft</td></tr>
<tr><td>1.1.3 SoG_Mat_2_150mm_Auditorium</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)]
= 19.86 ft</td></tr>
<tr><td colspan="3">1.2 Concrete Footing</td></tr>
<tr><td>3 Columns and Beams</td><td colspan="3">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. This being the case and given the complex shape of the CIRS building and the fact that all beams were wooden except for auditorium side beams which were conrete, we calculated every individual beam or grouped beams seperately in Autodesk QTO. There were numerous beams which were supported on primary beams rather then columns, all those beams are taken into extra base materials. Some of the beams calculated were of larger bay size and Athena did not allow input of those beams, all such beams were input into the Athena inventory in parts. The hollow structural steel (HSS) columns in the CIRS building were modeled in the Extra Basic Materials, where their associated assumptions and calculations are documented. All stairs were wooden, and composed of wood stingers and glulam beams, so all stair cases except for entrance stairs are modelled as beams.</td></tr>
<tr><td>4 Floors</td><td colspan="3">Furthermore, several flooring components were excluded in the model due to modeling limitations and uncertainty. The components not included were, carpet, epoxy sealants, and hydronic piping in concrete slabs.</td></tr>
</table>

	Suspended slab	Floor_F30_SUSPENDED-CONCRETE-SLAB-RAISED-TECRETE	All tecrete was calculated as cocnrete masonry in the extra base materials due to Athena's limitation to model any such material
5 Roof	Several roof components were excluded in the model due to modeling limitations and uncertainty. The components not included were, plant and growing medium, green roof root barrier and protection board.		
	5.1 Green Roof		
		Roof_R1_LAMINATED-WOOD-GREEN-ROOF	The detials of TPO were not found in Athena IE, so we used EPDM white, which is basically same as TPO
	5.2 Laminated wood		
		Roof_R2_LAMINATED-WOOD-PAVING-STONE	Roof widths were determined by dividing the total floor area of each condition by the span of that condition
6 Extra Basic Materials	All HSS sections were calculated in the extrabase material based on the density of 8000kg/m3		
	6.1 Steel pedestals		
		Pedestals for the raised floor	
			An estimate of weight for the raised-floor pedestals was determined by: 1) estimating the volume of each pedestal, .0006m3, 2) determining the count of each pedestal, count = ((number of tec-crete panels) 1/2 + 2)2 = 4803, and 3) determining the weight by combing outputs from 1 and 2 with the density of steel (8000 kgm-3).