Life Cycle Assessment of Vanier Residence in University of British Columbia

Building Performance and Environmental Impacts

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Abstract

This case study represents a portion of twelve individual buildings for the University of British Columbia (UBC). The buildings are divided into residential and academic for a functionally comparative view. Two programs: the Athena Environmental Impact Estimator (Impact Estimator or IE) and OnCenter's OnScreen TakeOff were used to create an LC model of the Vanier Residence.

For this case study, a cradle-to-gate life cycle assessment (LCA) was conducted on the Vanier Residence. The LCA conducted looks into the life cycle stages of manufacturing and construction only; commissioning, maintenance and operational effects are outside the scope.

The Vanier Residential primary energy consumption is estimated to be 288.43 MJ/ ft^2. Of this, 96.23% of the primary energy comes from the material manufacturing, while 3.77% comes from the transportation. To assess the reliability of the impact assessment, a sensitivity analysis ±10% was then conducted for the five largest material quantities. Consequently, concrete was found to be the major contributor in all environmental impact categories. To emphasize this, the environmental impacts of concrete were then compared as a function of the whole residence. It was found that the use of concrete as a percentage of the building, generates 89.56% ozone depletion, 72.8% acidification potential, 72.02% weighted resource use and 65.4% smog potential. Lastly, the building was assessed for operation energy reduction by upgrading the insulation with polyisocyanurate and calculating an energy payback period, which was 14 years.

The significance of developing an LCA model of Vanier Residence is explored in this case study, with future design implications and modeling methods discussed.

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1.0 Introduction

Worldwide- residential, commercial and institutional buildings play a major role in resource consumption. Consequently, environmental impacts from building material manufacture and production can be tied in as well. With the diminishing discovery of unscathed resources and increase awareness of environmental issues, it has pushed new designers and developers into sustainable and improved construction practices, mainly in the area of material choice. This case study investigates the design implication regarding heat lost and complexities in material selections for whole buildings.

1.1 Case Study Building Description

The case study is Vanier Residence which is built over a time period of 1959-1961 with a further expansion in 1968. Given the limited timeframe the expansion was not modeled. The Residence of interest consists of twelve building over a surface area of 600,000 ft^2 and contains 1,370 beds. Room size varies from 108 ft^2 and 194 ft^2 respectively. The building names of interest are as followed:

- Co-ed Houses: Cariboo, Hamber, Okanagan, Sherwood Lett, Tweedsmuir, and Mawdsley
- Women's Houses: Kootenay and Ross
- Men's Houses: Mackenzie and Robson

The facilities in each house include a study area, dining room, fitness room, and game room. Outside these building, a tennis and basketball court is located conveniently in the middle of the residence.

The Residence is divided into three different building units: Building A, Building B with lounges and Building C with lounges and elevators. Each Vanier Residence contains a basement, ground, second, third and fourth floor with a building footprint of

4844 ft^2 and 4991 ft^2 (Unit B) respectively. The ten residential buildings modeled in this report excludes the common block. A building description is shown as followed:

Table 1 Building Characteristic

Building System	Specific Characteristics of Vanier
Structure	Mainly concrete, with concrete bearing wall supporting the suspended slab
Floors	Basement: Concrete slab on grade; Ground, First, Second, Third and Fourth Floors: Suspended slabs
Exterior Walls	Basement: Cast in place; Ground, Second, Third and Fourth Floors: Concrete tilt up with brick - concrete cladding, extruded polystyrene, polyethylene 3mil, 5/8" plaster and aluminum frame doors
Interior Walls	Basement, Ground, First, Second, Third and Fourth Floors: Concrete tilt up walls and brick plaster wall with aluminum frame doors.
Windows	All windows are aluminum frame with a wood stud window sill.
Roof	Main Roof: 20 year bonded built up roof with precast trellis beam over hang. Insulation include polystyrene expanded

2.0 Goal of Study

This LCA of the Vanier Residence at the University of British Columbia was carried out as an exploratory study to determine the environmental impact of its design. This LCA of the Vanier Residence is also part of a series of twelve others being carried out simultaneously on respective buildings at UBC with the same goal and scope.

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

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

3.0 Scope of Study

The product system being studied in this LCA are the structure, envelope and operational energy usage associated with space conditioning of the Vanier Residential on a square foot finished floor area of residence building basis. In order to focus on design related impacts, this LCA encompasses a cradle-to-gate scope that includes the raw material extraction, manufacturing of construction materials and construction of the structure and envelope of the Vanier Residence, as well as associated transportation effects throughout.

4.0 Tools, Methodology and Data

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

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

Using the formatted takeoff data, version 4.0.51 of the IE software, the only available software capable of meeting the requirements of this study, is used to generate a whole building LCA model for the Vanier residence in the Vancouver region as a residential building type. The IE software is designed to aid the building community in making more environmentally conscious material and design choices. The tool achieves this by applying a set of algorithms to the inputted takeoff data in order to complete the takeoff process and generate a bill of materials (BoM). This BoM then utilizes the Athena Life Cycle Inventory (LCI) Database, version 4.6, in order to generate a cradle-to-grave LCI profile for the building. In this study, LCI profile results focus on the manufacturing and transportation of materials and their installation in to the initial structure and envelope assemblies. As this study is a cradle-to-gate assessment, the expected service life of the Vanier Residence is set to 1 year, which results in the maintenance, operating energy and end-of-life stages of the building's life cycle being left outside the scope of assessment.

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

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

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

The primary sources of data for this LCA are the original architectural and structural drawings from when the Vanier Residence was initially constructed in 1962. The assemblies of the building that are modeled include the foundation, columns and beams, floors, walls and roofs, as well as the associated envelope and openings (ie. doors and windows) within each of these assemblies. The decision to omit other building components, such as flooring, electrical aspects, HVAC system, finishing and detailing, etc., are associated with the limitations of available data and the IE software, as well as to minimize the uncertainty of the model. In the analysis of these assemblies, some of the drawings lack sufficient material details, which necessitate the usage of assumptions to complete the modeling of the building in the IE software. Furthermore, there are inherent assumptions made by the IE software in order to generate the bill of materials and limitations to what it can model, which necessitated further assumptions to be made. These assumptions and limitation will be discussed further as they energy in the Building Model section and, as previously mentioned, all specific input related assumption are contained in the Input Assumptions document in Annex B.

5.0 Building Model

The Vanier 1960 blueprints were obtained in the UBC Building Development Archives. From this, the building was modeled using two software: OnScreen, a takeoff software and Athena Environmental Impact Estimator.

The following sections describe the assumptions made in converting the material takeoff file into a suitable format for the IE software. From here a Bill of Materials was generated from the IE to be used for material assessment. The top five materials are discussed in terms of theirs assemblies and the uncertainties associated with it. Finally, the building model will be summarized as a whole life cycle stage and by assembly groups.

5.1 Takeoffs

During the modeling progress there were certain challenges from the old blueprints. Readability became the sources of some issues, such as writing legibility. OnScreen was incorporated to fill in missing dimensions as well as improving takeoff efficiency. A combination of Onscreen and legible dimensions were used in our building model. From quantifying to qualifying on the IE, it was noted that some materials were not in the database. Attempts to model the material as alternative materials were incorporated into the take off file. Materials that possess modest amount or distinct attribute that were not included in IE were omitted; example of this includes light weight concrete overlay and bolts.

The Vanier Residential Building is divided into three building units with Building A as the base model. Unit C has the addition of one lounge per level with each lounge taking the place of two rooms. For Unit B, the lounges are also a factor as well an elevator installment that increases the building exterior wall and concrete foundations. Concrete specifications on fly-ash percentage were modeled using industrial averages due to missing information. Other global assumptions were made in regard to unfinished architectural drawings. For the basement plans of Unit A, three walls were included in the basement by inspections that were not mentioned in the drawings.

The main assembly assumptions are listed as follows. For a detail listing of these assumptions please refer to Appendix B.

5.1.1 Foundation

The foundation of Vanier Residence is made of slab on grade. The thickness was rounded from 6” to 8” because of Athena software limitation. In this way, the over estimation would be more suitable to adjust for overlooked concrete in the building model, such as light weight concrete. Specification on the slab requires water proofing; a 6 mil polyethylene vapour barrier was chosen due to IE solitary vapour barrier selection.

5.1.2 Floors

The floors consist of suspended slab with #5 Rebar. Details on flyash percentages were modeled using industrial averages due to missing data. Additionally, the suspended slabs loading and live load were unspecified. As a result, consultation from a civil engineer suggests that these values be maximized, due to weight distribution from the above floors.

5.1.3 Wall

For Vanier there are two exterior and two interior walls. The two exterior wall for Vanier was limited by thickness. Correspondingly the 10" thick concrete wall was rounded up to 12," while concrete part of the concrete brick wall was rounded down from 6" to 5 ½". The larger area represented by the concrete brick wall is more then enough to create an underestimation in the total concrete volume in the wall, which is then compensated by the overestimation in the foundation.

Lastly an assembly for a 4" brick plaster wall was unavailable in IE. The brick plaster wall was modeled by tons with the plaster omitted.

5.1.4 Roof

The roof was modeled as a concrete suspended slab roof. It was assume that the light weight concrete overlay is equivalent to concrete topping. As discussed, this concrete will be compensated by the foundation. The specification for the roof loading was unspecified. Contrary to this, a civil engineer was consulted for the possible loading specification. The loading was minimize because no structural integrity was intended for public use.

The upper and lower roof both contains a precast trellis beam overhang. This beam over hang was superimposed as a roofing assembly due to its similarities to a concrete precast double T roof.

5.1.5 Stairs

The stairs were modeled as concrete footing foundation for consistency between the residential in UBC. This assumption was made because the stairwell is used only for walking such that no possessions are meant to be located on the stairwells. Consequently, a lower grade concrete can be used; for this case, concrete footing foundation was selected based on the minimal load requirements.

5.1.6 Extra Base Material

The extra base material was used to model some building components that were not included in IE. One example was acoustic T. OH Gypsum which was model as gypsum board. Another structure was the column supporting the lower roof over hang. The columns were divided into concrete and brick volume. For the brick, this volume was then multiplied into tons in order to be inputted into IE.

5.2 Bill of Material

Using the IE inputs developed from the takeoffs a Bill of Materials (BoM – Table 2) was generated in the IE. Looking at the largest five materials, we can associate it with the walls which compose of Concrete 60 Mpa, polyethylene, regular gypsum board and polyethylene. A close second is concrete 20 Mpa which is the slab on grade and the roofing material.

The Concrete 20 Mpa was overestimated due to limitation in thickness in IE. The thickness of 6” was rounded to 8” and consequently an over estimation in thickness is about 33.3%. Since the concrete is specified in volume this over estimation results in an error of concrete volume by an equivalent amount, 33.3%. This amount is offset by the reduction in 6”concrete in the exterior wall to 5 ½”. Despite this, it is believe that the overall concrete volume is slightly overestimated. On the other hand, concrete 60 Mpa refers to suspended slab and has an arbitrary thickness. It is believe that this number is an over estimation since suspended slab requirement is tougher then slab on grade which suggest a thickness greater then 6”.

Table 2 Bill of Materials

Material	Quantity	Unit
3 mil Polyethylene	191671.8242	ft2
5/8" Regular Gypsum Board	91218.90872	ft2
6 mil Polyethylene	335813.899	ft2
Aluminum	101.1286	Tonnes
Batt. Fiberglass	3391.500439	ft2 (1in)
Brick Type 2	7773.4056	Tonnes
Cold Rolled Sheet	1.027	Tonnes
Concrete 20 MPa (flyash av)	274361.9566	ft3
Concrete 30 MPa (flyash av)	280.4655529	ft3
Concrete 60 MPa (flyash av)	381319.2869	ft3
Concrete Brick	57464.35118	ft2
EPDM membrane	9651.539765	lbs
Expanded Polystyrene	48489.15831	ft2 (1in)
Extruded Polystyrene	82946.08361	ft2 (1in)
Glazing Panel	62.9694	Tonnes
Joint Compound	8.1283	Tonnes
Mortar	3500.594606	ft3
Nails	2435.2574	Tonnes
Paper Tape	0.0933	Tonnes
Rebar, Rod, Light Sections	658.219	Tonnes
Small Dimension Softwood Lumber, Green	328.9843737	ft3
Softwood Plywood	12492.2145	ft2 (1in)
Standard Glazing	75452.26853	ft2
Welded Wire Mesh / Ladder Wire	26.7728	Tonnes

For the polyethylene it was noted that 6 mil polyethylene has a area of 335813.9 ft^2 while 3mil polyethylene has 191671.82 ft^2. Knowing that the 6 mil polyethylene comes only from the slab on grade and that this area is smaller then the exterior wall covered by the 3 mil polyethylene it shows a significantly larger waste factor associated with the 6 mil polyethylene.

6.0 Summary Measure

Based on the assemblies inputted into the IE, the Summary Measures were generated in Appendix C. Looking at the primary energy consumption Vanier Residential is estimated to consume 288.43 MJ/ ft^2. Of this energy consumption, material constitute for 96.23% of the energy consumption with 3.77% resulting from transportation. The percentages of these total impact categories were then divided by assembly group Table 3 to show the sources of the impacts. In this case, the walls and floors were the main components to these impacts with 78% of the embodied energy consumptions.

One of the major assumptions made was modeling the 4” brick plaster interior walls as Brick in tons and omitting the plaster. Because of this, there is a significant underestimation in terms of plaster content.

To check the reliability of the final results and conclusion the uncertainties in the data were verified by a sensitivity analysis of ±10% of individual materials. The materials that were chosen were based on the largest quantity in volume, weight, and area (Table 2).

Table 3: Percentage Impacts Per Assembly Group

Material ID	Foundations	Walls	Roofs	Floors	Extra Basic Material
Primary Energy Consumption MJ	7.27	75.48	2.54	14.67	0.31
Weighted Resource Use kg	23.31	38.59	5.78	32.19	0.13
Global Warming Potential (kg CO2 eq / kg)	11.62	63.44	3.02	21.85	0.07
Acidification Potential (moles of H+ eq / kg)	13.16	59.50	3.25	24.02	0.08
HH Respiratory Effects Potential (kg PM2.5 eq / kg)	11.60	63.54	3.02	21.79	0.07
Eutrophication Potential (kg N eq / kg)	6.13	79.59	1.95	12.28	0.06
Ozone Depletion Potential (kg CFC-11 eq / kg)	11.60	63.52	3.02	21.80	0.07
Smog Potential (kg NOx eq / kg)	11.63	63.45	3.02	21.84	0.07

6.1 Sensitivity Analysis

A sensitivity analysis was conducted by individually varying the material content in the Vanier building model. A 5% waste reduction was included for polystyrene insulation due to the additional insulation added by the IE to compensate for wastes during insulation installations.

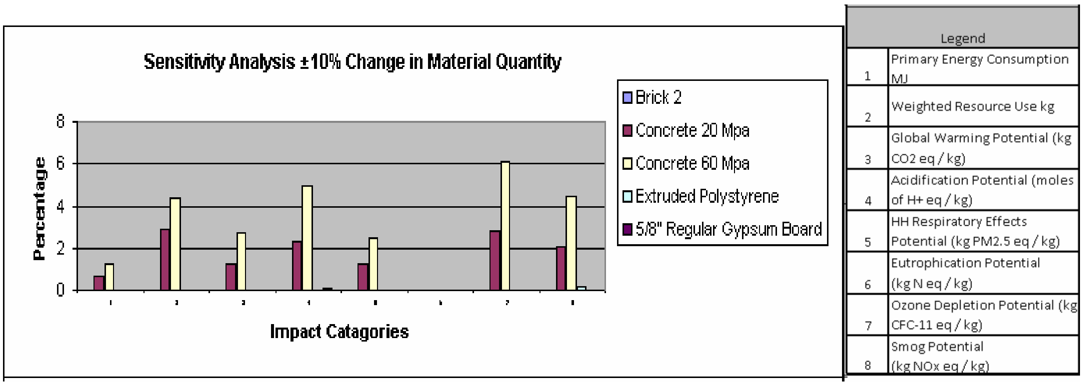

Figure 1: Sensitivity Analysis

Table 4: Normalized Concrete Impacts of Whole Building

Legend	% Concrete	% Percentage
1	1.900	19.003
2	7.202	72.024
3	3.972	39.717
4	7.283	72.832
5	3.717	37.172
6	0.0382	0.382
7	8.957	89.568
8	6.542	65.420

Looking at the Sensitivity Analysis in Figure 1, concrete 20 Mpa and 60 Mpa constitute for most of the environmental impacts in all categories except for eutrophication, which is the least impacted overall. The IE uses a linear model; correspondingly, we can manually subtract 100% of the quantity to determine the impact of each material category. To this regard, percentage changes in impact category were divided by the percentage material change in order to calculate the net impact of the material as a function of the building impact. The concrete impacted are summarized in Table 4. From the table, concrete constitutes for more then 89.56% of ozone depletion, 72.8% acidification potential, 72.02% weighted resource use and 65.4% smog potential. On the other hand brick extruded polystyrene and 5/8" regular gypsum board have almost non-existent impacts on the overall buildings.

Taking a step back, and looking at the global aspects of the building. The use of concrete as the main building components has a significantly large amount of the environmental impacts of the whole building. An LCA performed in the design stage may be able swap the concrete for other equivalent materials such as steel and wood. One study compares the embodied energy, global warming potential, air emission index, water emission index and solid waste to wood substitution in concrete and steel frame. As noted by CORRIM (Consortium for Research on Renewable Industrial Materials), "all of the index measures had considerably lower environmental risk for the wood frame designs in Atlanta and Minneapolis compared to the non-wood frame designs". There is also no regulation prohibiting such wooden framework for Vanier Housings. For the British Columbia Building Code 2006, a four storey wooden building can be built up to an area of $1800m^2$which is lower then the foundation area 4844 ft^2 - 473 m^2 (Appendix D). A rough simulation of the exterior wall in concrete block and wood stud were compared over a 60 year period in the IE and verifies CORRIM assessment (Figure 2 & 3, Appendix E).

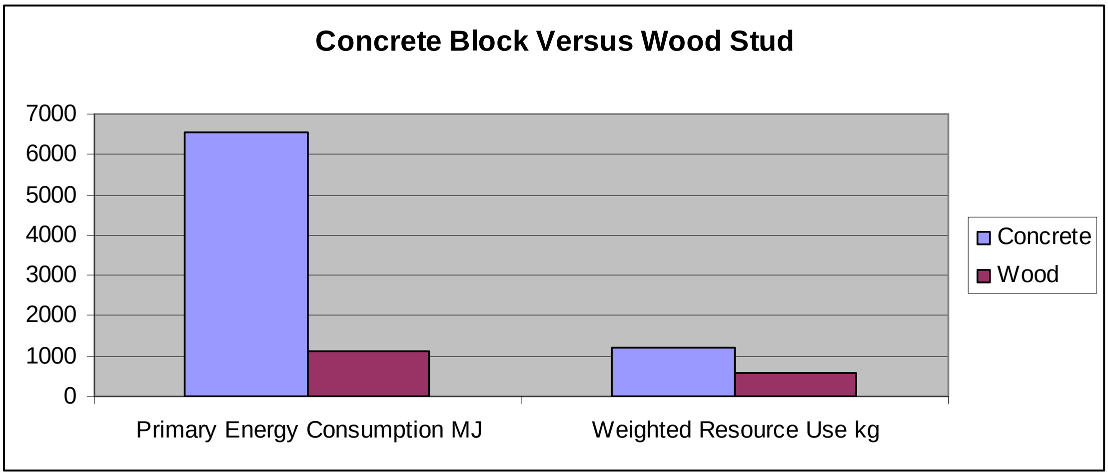

Figure 2: Concrete Versus Wood Frame (A)

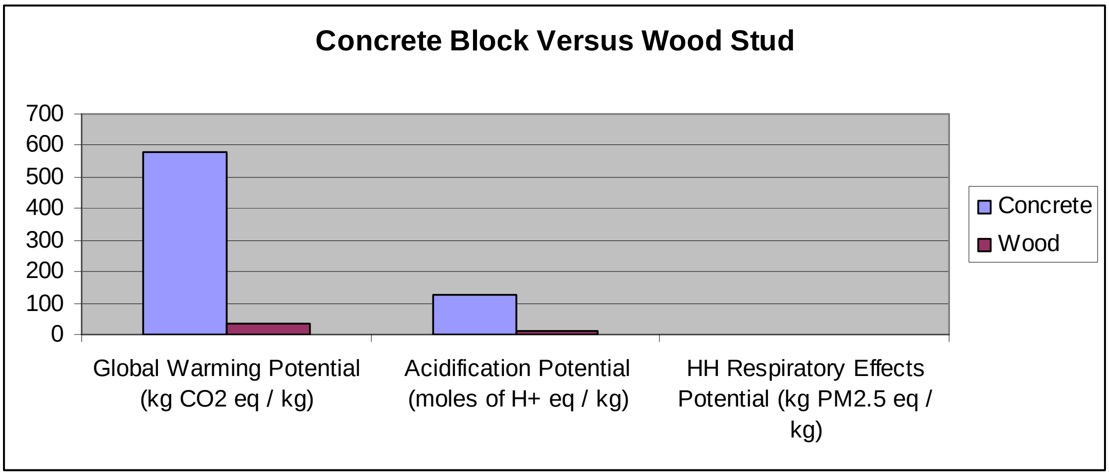

Figure 3: Concrete Versus Wood Frame (B)

Currently the use of wood framing can be done, but is not widely use due to public concerns on earthquakes stability, fire rating and environmental protection. For a full spectrum in wall equivalency, an LCA swapping the concrete for a wood-concrete frame will require additional expertise that is out of the scope of this report. Nether less, the sensitivity analysis shows the large impacts in using concrete. With the embodied energy from manufacturing and construction quantified, we can begin to look at operational energy over time.

7.0 Building Performance

In order to reduce operational energy the building was assessed for new insulation and new windows to meet UBC REAP standards.

Residential Environmental Assessment Program's (REAP's) insulation requirements;

- EA 1.1; Roof – minimum R-40
- EA 1.2; Exterior Wall Insulation – minimum R-18
- EA 1.3; Energy Star Windows – minimum R-3.2

To meet these standards, 1” and 4.34” polysocyanurate was added to the walls and roof respectively. The windows were upgraded from standard glazing single to Low E silver argon filled glazing (3mm glass with 1/2" airspace). The energy loss was then modeled using the following formula with average historical temperature taken from the Civil 498 database for consistency. The results were shown in Appendix Figure 4.

Energy Equation: $Q = (1/R) \times A \times \Delta T$

Assembly	Area (ft2)	R-Value (ft2.degF.h/BTU) 'Current' Building	R-Value (ft2.degF.h/BTU) 'Improved' Building
Exterior Wall 10"C	2903.75	11.23	18
Window	101.2695313	1.68	3.75
Exterior Wall 6"C 4"B	12667.08333	12.32	18
Window	2175.744792	1.68	3.75
Roof	4407	8.765	40
Weighted Average	22254.84766	10.39	20.90

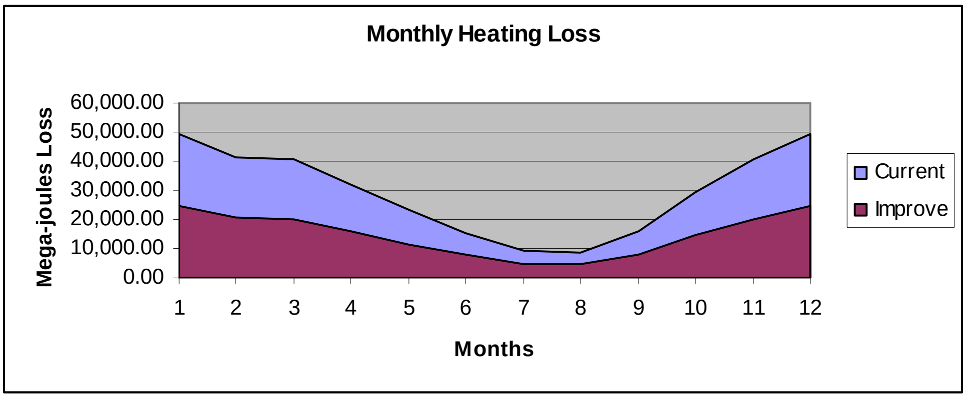

Figure 4 Monthly Energy Consumption

The energy modeled showed that the improve insulation had reduced the energy loss by about 50%, but because we have chosen energy intensive materials, the initial embodied energy will be greater and will be paid off in time. Using the IE, the building was modeled for the insulated and improved insulated case for a span of 80 years. For this case, the payback period was fourteen years as shown in Figure 5.

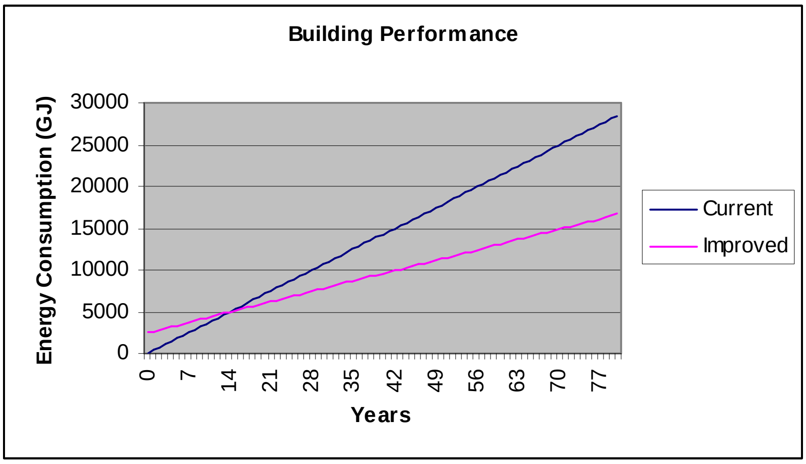

Figure 5: Building Performance - Payback Period

As well as the cost of embodied energy the cost of improved insulation will also cause additional environmental consequences. Currently these environmental impacts are unregulated and unaccounted for in insulation design. These environmental impacts will have to be accounted for in future insulation sizing. For this case the additional polyisocyanurate environmental impacts are summed up in Table 5.

Table 5: Improved Insulation Environmental Impacts

Impact Catagory	Difference
Primary Energy Consumption MJ	2481491.63
Weighted Resource Use kg	145631.92
Global Warming Potential (kg CO2 eq / kg)	249239.69
Acidification Potential (moles of H+ eq / kg)	50511.79
HH Respiratory Effects Potential (kg PM2.5 eq / kg)	185.072
Eutrophication Potential (kg N eq / kg)	0.24
Ozone Depletion Potential (kg CFC-11 eq / kg)	0.00021
Smog Potential (kg NOx eq / kg)	326.46

It is important to understand that environmental designs were almost non-existent in historical buildings due to limited awareness. Presently, these environmental costs are still largely unpaid for and are steadily increasing as a result of a one sided view in operating savings. The other residential building and their higher embodied effects is believed to follow the same one sided view, which explains the increasing trend in the residence energy consumption per square feet. A study into 1970s and modern home built to R2000 standards show that a relatively small increase in embodied material effects are more than offset by significant reductions in related operating energy burdens (Meil 2002). For the residences, it appears that the same tradeoff is being made (Table 6); further studies will be needed to verify this claim.

By looking into the impacts of differing insulation it can provide guidelines in benchmarking insulation materials in terms of environmental friendless. In the case of Vanier Residence, the additional insulation could be added on top of the insulated area, while windows, it may be better leave untouched due to the cost in un-installment and installment of the new windows.

Table 6: Residence Aggregated Summary Measures

		Vanier	Totem	Gage	Fariview	Thunder bird	MarineDr ive	Average
Impact Category	**Units**	1968	1964	1972	1985	1995	2005	
Primary Energy Consumption	MJ	288.43	404.14	328.49	282.91	495.45	963.82	460.54
Weighted Resource Use	kg	116.42	196.50	182.15	99.98	182.69	597.22	229.16
Global Warming Potential	(kg CO2 eq / kg)	20.11	29.56	25.64	16.74	28.40	77.88	33.05
Acidification Potential	(moles of H+ eq / kg)	3.66	10.13	10.65	7.03	6.10	27.03	10.77
HH Respiratory Effects Potential	(kg PM2.5 eq / kg)	0.05	0.08	0.13	0.09	0.07	0.26	0.12
Eutrophication Potential	(kg N eq / kg)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ozone Depletion Potential	(kg CFC-11 eq / kg)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Smog Potential	(kg NOx eq / kg)	0.06	0.14	0.18	0.09	0.10	0.42	0.16

It is inherent that most decisions logistically are determined by cost factors. As a contractor do you lower your material quality to reduce your bid cost? Or do you increase your cost at risk of losing your bid? This financial cost for contractors can be easily diverted by *differing* this cost to the owner. One method that differ these cost are the use of green labeling which provides incentives for owners to reduce their building ecological footprint, which will appeal to the market and offer a return in investment in subsequent years.

To conclude, the cost of improved insulation will require a pay back period of fourteen years and additional environmental impacts; following this, a return on investment will occur in future years. To make this tradeoff on environmental impacts and cost, a LCA practitioner can help owners make informed decisions.

8.0 Conclusion

An LCA study was conducted on Vanier Residence which constitute from ten buildings. The product system in the LCA of Vanier encompasses a cradle-to-gate scope that results in a 96.23% energy consumption that arises from the material manufacturing effects with 3.77% resulting from transportation effects. Because of the large consumption of energy that arises from the material manufacturing, the production of material becomes a significant concern in impact assessment. By setting comparative standards for the all the impact categories: primary energy consumption, weighted resource use, global warming potential, acidification potential, HH respiratory effects, ozone depletion potential smog potential and eutrophication potential. LCA practitioners can begin to make trade-off between materials for assembly use.

From the assessment, it was discovered that there is a large impact that arises from the main structure of the building; for this case, it was concrete. An overview comparing wood and concrete exterior wall shows that the environmental impacts resulting from concrete use is much larger then a wood frame in terms of global warming potential, acidification potential and primary energy use. This implication suggests that we look into alternative materials that offer the same structural integrity as concrete but offer a lower impact across all the impact categories. Development for future green practices should start on the largest material impact in order to reduce the impact of the overall buildings.

For Vanier Residence a sensitivity analysis was conducted to see the significance of a ±10% change in five of the largest material quantities. The tables point out that concrete is the largest contributor in most categories. Since the IE uses a linear modeling of impact assessment, the normalized result showed that concrete constitutes for more then 89.56% of ozone depletion, 72.8% acidification potential, 72.02% weighted resource use and 65.4% smog potential as a percentage of the whole building. The implications of alternative materials such as wood or steel frame were discussed. A summary of the impacts comparing wood and concrete frame work show that a wood frame can reduce the ecological footprint of Vanier.

Lastly, the building performance was assessed for operational usage by upgrading the insulation to REAP standards.

- EA 1.1; Roof – minimum R-40
- EA 1.2; Exterior Wall Insulation – minimum R-18
- EA 1.3; Energy Star Windows – minimum R-3.2

To meet REAP standards the installation of polyisocyanurate insulation was used. On assessment, polyisocyanurate insulation offers a fourteen year embodied energy payback period with an increase in environmental impacts. This LCA on Vanier Residence explores the uses of alternative framing material as well as materials for improve envelope performance. The discussion signifies the importance of additional research into material selection for reduce environmental impacts. Future guidelines on environmental impacts amounts would do well in limiting impacts from buildings by pushing more sustainable designs. In addition, further comparison on cost will be needed to accompany the environmental impacts in order to select the most appropriate materials for our buildings.

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Appendix A: EIE Inputs

ATHENA® Environmental Impact Estimator **Typical Floor (234)**					
General Description					
	Project Name		Vanier		
	Project Location		UBC		
	Building Life Expectancy		1		
	Building Type		Residential		
	Operating Energy Consumption		N/A		
Assembly Group	**Assembly Type**	**Assembly Name**	**Input Fields**	**Input Values**	
				Known/Measured	IE Inputs
2 Floors				-	
	2.1 Suspended Slab				
		2.1.1 - Suspended Slab 4 1/2"			
			Roof Width (ft)	58.67	58.67
			Span (ft)	58.67	58.67
			Concrete (psi)		9000
			Concrete Flyash %		average
			Live Load (psf)		100
		2.2.2 - Suspended Slab 5"			
			Roof Width (ft)	24.88	24.88
			Span (ft)	24.88	24.88
			Concrete (psi)		9000
			Concrete Flyash %		average
		2.2.3 - Suspended Slab 6"			
			Roof Width (ft)	10.2	10.2
			Span (ft)	10.2	10.2
			Concrete (psi)		9000
			Concrete Flyash %		average
			Live Load (psf)		100
3 Custom					

Wall					
	3.2 Concrete Tilt Up				
		3.1.2 - Exterior 6" Concrete 4" Brick			
			Wall Type	Exterior	Exterior
			Length (ft)	363	363
			Height (ft)	8.416666667	8.416666667
			Thickness	6"	5 1/2"
			Concrete (psi)		9000
			Concrete Flyash %		Avg
			Rebar	8	6
			Status	Operable	Operable
			Number of window units	31	31
			Frame Type	Aluminum Frame	Average
		Opening Types	Glazing Type (double pane glazings)	-	Standard Glazing
		Envelope	Envelope Category	Water proof	Vapour Barrier
			Envelope Material		polyethylene
			Thickness		3 mil
			Envelope Category		Gypsum Board
			Envelope Material	Plaster	Gypsum Regular
			Thickness	5/8	5/8"
			Envelope Category	Insulation	
			Envelope Material	Styrofoam	Polystyrene Extruded
			Thickness	1"	1"
			Envelope Category	Cladding	
			Envelope Material	Brick	Brick - Concrete
			Thickness	4"	-
		3.1.3 - Interior 6" Concrete			
			Wall Type	Exterior	Exterior
			Length (ft)	289	289
			Height (ft)	8.416666667	8.416666667
			Thickness	6	5 1/2"
			Concrete (psi)		9000
			Concrete Flyash %		Avg
			Rebar	8	5
			Door Type	Aluminum Frame	Aluminum exterior frame 80% glazing
			Door #	27	27
		Envelope	Envelope Category	Water proof	Vapour Barrier
			Envelope Material		polyethylene
			Thickness		3 mil

	3.2 Extra Material				
		3.2.1 - Interior 4" Brick Plaster			
			Envelope Material	Brick Plaster 4"	Brick Type 2
			Weight (Tons)	673.2963	673.2963
	3.2 Wood Stud				
		3.2.1 Window Sill			
			Wall Type	Interior	Interior
			Length	74.6	74.6
			Height	4	4
			Sheathing Type	Plywood	Plywood
			Stud Spacing		25 o.c.
			Stud Type		Green Lumber
			Stud Thickness	2x6	2x6

Inputs to Model
Single Unit A

General Description					
	Project Name		Vanier		
	Project Location		UBC		
	Building Life Expectancy		1		
	Building Type		Residential		
	Operating Energy Consumption		-TBA-		
Assembly Group	**Assembly Type**	**Assembly Name**	**Input Fields**	**Input Values**	
				Known/Measured	IE Inputs
1 Foundation					
	1.1 Concrete Slab on Grade				
		1.1.1 - Concrete Slab on Grade 6"			
			Length (ft)	69.27481505	69.27481505
			Width (ft)	69.27481505	69.27481505
			Thickness (in)	6	8
			Concrete (psi)	3000	3000

		Define Envelop	Concrete Flyash %		average
			Category		Vapour barrier
			Material	Water proof	polyethylene
			Thickness		6 mil
2 Floors					-
	2.1 Suspended Slab				
		2.1.1 - Suspended Slab 4 1/2"			
		Extra basic Material (ceiling)	Roof Width (ft)	118.6296759	118.6296759
			Span (ft)	118.6296759	118.6296759
			Concrete (psi)		9000
			Concrete Flyash %		average
			Live Load (psf)		100
			Envelope Category	Gypsum Board	
			Envelope Material	3/4" Acoustic T. OH Gypsum	5/8" Regular Gypsum Board
			Area	323	323
			Envelope Category	Insulation	323
			Envelope Material	Batt. Fiberglass	Batt. Fiberglass
			Area	323	323
		2.1.2 - Suspended Slab 5"			
			Roof Width (ft)	49.65883607	49.65883607
			Span (ft)	49.65883607	49.65883607
			Concrete (psi)		9000
			Concrete Flyash %		average
			Live Load (psf)		100
		2.1.3 - Suspended Slab 6"			
			Roof Width (ft)	20.39607805	20.39607805
			Span (ft)	20.39607805	20.39607805
			Concrete (psi)		9000
			Concrete Flyash %		average
			Live Load (psf)		100
3 Custom Wall					
	3.1 Cast In Place				
		3.1.1 - Exterior 10" Concrete			
			Wall Type	Exterior	Exterior
			Length (ft)	345	345
			Height (ft)	8.416666667	8.416666667
			Thickness	10	12
			Concrete		9000
			Concrete Flyash %		Avg

			Reinforcement		6
			Door Type	Aluminum Frame	Aluminum exterior frame 80% glazing
			Door #	4	4
			Status	Inoperable	Inoperable
			Number of window units	9	9
			Frame Type	Aluminum Frame	Average
		Opening Types	Glazing Type (double pane glazings)	-	Standard Glazing
		Envelope	Envelope Category	Water proof	Vapour Barrier
			Envelope Material		polyethylene
			Thickness		3 mil
			Envelope Category		Gypsum Board
			Envelope Material	Plaster	Gypsum Regular
			Thickness	5/8	5/8"
			Envelope Category	Insulation	-
			Envelope Material	Styrofoam	Polystyrene Extruded
			Thickness	1"	1"
			Envelope Category	Cladding	-
	3.2 Concrete Tilt Up				
		3.2.1 - Exterior 6" Concrete 4" Brick			
			Wall Type	Exterior	Exterior
			Length (ft)	1505	1505
			Height (ft)	8.416666667	8.416666667
			Thickness	6"	5 1/2"
			Concrete		9000
			Concrete Flyash %		Avg
			Rebar	8	6
			Door Type	Aluminum Frame	Aluminum exterior frame 80% glazing
			Door #	3	3
			Status	Inoperable	Inoperable
			Number of window units	123	123
			Frame Type	Aluminum Frame	Average
		Opening Types	Glazing Type (double pane glazings)	-	Standard Glazing
		Envelope	Envelope Category	Water proof	Vapour Barrier
			Envelope Material		polyethylene
			Thickness		3 mil
			Envelope Category		Gypsum Board
			Envelope Material	Plaster	Gypsum Regular
			Thickness	5/8	5/8"

			Envelope Category	Insulation	-
			Envelope Material	Styrofoam	Polystyrene Extruded
			Thickness	1"	1"
			Envelope Category	Cladding	-
			Envelope Material	Brick	Brick - Concrete
			Thickness	4"	-
		3.2.2 - Interior 6" Concrete			
			Wall Type	Exterior	Exterior
			Length (ft)	1439	1439
			Height (ft)	8.416666667	8.416666667
			Thickness	6	5 1/2"
			Concrete		9000
			Concrete Flyash %		Avg
			Rebar	8	6
			Door Type	Aluminum Frame	Aluminum exterior frame 80% glazing
			Door #	121	121
		Envelope	Envelope Category	Water proof	Vapour Barrier
			Envelope Material		polyethylene
			Thickness		3 mil
	3.3 Extra Material				
		3.3.1 - Interior 4" Brick Plaster			
			Envelope Material	Brick Plaster 4"	Brick Type 2
			Weight (Tons) Unit A, C	673.2963	673.2963
			Weight (Tons) Unit B	643.8447	643.8447
	3.4 Wood Stud				
		3.4.1 Window Sill			
			Wall Type	Interior	Interior
			Length	29.91	29.91
			Height	29.91	29.91
			Sheathing Type	Plywood	Plywood
			Stud Spacing		25 o.c.
			Stud Type		Green Lumber
			Stud Thickness	2x6	2x7
4 Roof					
	4.1 Concrete Suspended Slab Roof				
		4.1.1 Upper Roof			
			Floor/roof width (ft)	68.16	68.16
			Span (ft)	68.16	68.16
			Live load (psia)	-	45
			Concrete (psi)	-	3000

		Define Envelope	Type	Bonded Built Up Roof	Concrete Suspended Slab Roof
			Flyash %	average	
			Category	Insulation	
			Material	Rigid Insulation	Polystyrene Expanded
			Thickness	1"	1"
		4.1.2 Lower Roof			
			Floor/roof width (ft)	594	594
			Span (ft)	1	1
			Live load (psia)	-	45
			Concrete (psi)	-	3000
			Flyash %	-	average
	4.2 Concrete Precast Double T Roof				
		4.2.1 Upper Roof Overhang			
			Type	Precast Trellis Beam	Precast Double T Roof
			Number of Bays	25	594
			Bay Size (ft)	5.083333333	5.083333333
			Span (ft)	1	1
			Live Load	-	45
			With or W/out Concrete Topping	With	With
		4.2.2 Lower Roof Overhang			
			Type	Precast Trellis Beam	Precast Double T Roof
			Number of Bays	16	16
			Bay Size (ft)	3.833333333	3.833333333
			Span (ft)	0.5	0.5
			Live Load	-	45
5 Stairs			With or W/out Concrete Topping	With	With
	5.1 Concrete Footing Foundation				
		5.1.1 Stairs			
			Length (ft)	73	73
			Width (ft)	4.1666	4.1666
			Thickness	6	7.5
			Concrete		9000
			Concrete Flyash %		Avg
			Rebar	5	5
6 Column					
	6.1 Extra Basic Materials				

		6.1.1 Column Core			
			Concrete (yd3) 3000 psi, Average Flyash	4.09	4.09
		6.1.2 Brick Plaster 4"			
			Concrete Brick (Ton)	673.2963	673.2963

		Inputs to Model Single Unit B			
General Description					
	Project Name		Vanier		
	Project Location		UBC		
	Building Life Expectancy		1		
	Building Type		Residential		
	Operating Energy Consumption		-TBA-		
Assembly Group	**Assembly Type**	**Assembly Name**	**Input Fields**	**Input Values**	
				Known/Measured	IE Inputs
1 Foundation					
	1.1 Concrete Slab on Grade				
		1.1.1 - Concrete Slab on Grade 6"			
			Length (ft)	70.328	70.328
			Width (ft)	70.328	70.328
			Thickness (in)	6	8
			Concrete (psi)	3000	3000
			Concrete Flyash %		average
		Define Envelop	Category		Vapour barrier
			Material	Water proof	polyethylene
			Thickness		6 mil
2 Floors				-	
	2.1 Suspended Slab				
		2.1.1 - Suspended Slab 4 1/2"			
			Roof Width (ft)	118.6296759	118.6296759
			Span (ft)	118.6296759	118.6296759

			Concrete (psi)		9000
			Concrete Flyash %		average
			Live Load (psf)		100
		Extra basic Material (ceiling)			
			Envelope Category	Gypsum Board	
			Envelope Material	3/4" Acoustic T. OH Gypsum	5/8" Regular Gypsum Board
			Area	323	323
			Envelope Category	Insulation	323
			Envelope Material	Batt. Fiberglass	Batt. Fiberglass
			Area	323	323
		2.2.2 - Suspended Slab 5"			
			Roof Width (ft)	49.65883607	49.65883607
			Span (ft)	49.65883607	49.65883607
			Concrete (psi)		9000
			Concrete Flyash %		average
			Live Load (psf)		100
		2.2.3 - Suspended Slab 6"			
			Roof Width (ft)	23.73	23.73
			Span (ft)	23.73	23.73
			Concrete (psi)		9000
			Concrete Flyash %		average
			Live Load (psf)		100
3 Custom Wall					
	3.1 Cast In Place				
		3.1.1 - Exterior 10" Concrete			
			Wall Type	Exterior	Exterior
			Length (ft)	345	345
			Height (ft)	8.416666667	8.416666667
			Thickness	10	12
			Concrete		9000
			Concrete Flyash %		Avg
			Reinforcement		6
			Door Type	Aluminum Frame	Aluminum exterior frame 80% glazing
			Door #	4	4
			Status	Inoperable	Inoperable
			Number of window units	9	9
			Frame Type	Aluminum Frame	Average
			Glazing Type (double pane glazings)	-	Standard Glazing
		Opening Types	Envelope Category	Water proof	Vapour Barrier

		Envelope	Envelope Material		polyethylene
			Thickness		3 mil
			Envelope Category		Gypsum Board
			Envelope Material	Plaster	Gypsum Regular
			Thickness	5/8	5/8"
			Envelope Category	Insulation	-
			Envelope Material	Styrofoam	Polystyrene Extruded
			Thickness	1"	1"
			Envelope Category	Cladding	-
	3.2 Concrete Tilt Up				
		3.2.1 - Exterior 6" Concrete 4" Brick			
			Wall Type	Exterior	Exterior
			Length (ft)	1675.625	1675.625
			Height (ft)	8.416666667	8.416666667
			Thickness	6"	5 1/2"
			Concrete		9000
			Concrete Flyash %		Avg
			Rebar	8	6
			Door Type	Aluminum Frame	Aluminum exterior frame 80% glazing
			Door #	3	3
			Status	Inoperable	Inoperable
			Number of window units	123	123
			Frame Type	Aluminum Frame	Average
			Glazing Type (double pane glazings)	-	Standard Glazing
			Envelope Category	Water proof	Vapour Barrier
		Opening Types	Envelope Material		polyethylene
		Envelope	Thickness		3 mil
			Envelope Category		Gypsum Board
			Envelope Material	Plaster	Gypsum Regular
			Thickness	5/8	5/8"
			Envelope Category	Insulation	-
			Envelope Material	Styrofoam	Polystyrene Extruded
			Thickness	1"	1"
			Envelope Category	Cladding	-
			Envelope Material	Brick	Brick - Concrete
			Thickness	4"	-
		3.2.2 - Interior 6" Concrete			
			Wall Type	Exterior	Exterior
			Length (ft)	1471.5	1471.5

			Height (ft)	8.416666667	8.416666667
			Thickness	6	5 1/2"
			Concrete		9000
			Concrete Flyash %		Avg
			Rebar	8	6
			Door Type	Aluminum Frame	Aluminum exterior frame 80% glazing
			Door #	121	121
		Envelope	Envelope Category	Water proof	Vapour Barrier
			Envelope Material		polyethylene
			Thickness		3 mil
	3.3 Extra Material				
		3.3.1 - Interior 4" Brick Plaster			
			Envelope Material	Brick Plaster 4"	Brick Type 2
			Weight (Tons)	643.8447	643.8447
	3.4 Wood Stud				
		3.4.1 Window Sill			
			Wall Type	Interior	Interior
			Length	29.91	29.91
			Height	29.91	29.91
			Sheathing Type	Plywood	Plywood
			Stud Spacing		25 o.c.
			Stud Type		Green Lumber
			Stud Thickness	2x6	2x7
4 Roof					
	4.1 Concrete Suspended Slab Roof				
		4.1.1 Upper Roof			
			Floor/roof width (ft)	4407	4407
			Span (ft)	1	1
			Live load (psia)	-	45
			Concrete (psi)	-	3000
			Type	Bonded Built Up Roof	Concrete Suspended Slab Roof
			Flyash %	average	
		Define Envelope	Category	Insulation	
			Material	Rigid Insulation	Polystyrene Expanded
			Thickness	1"	1"
		4.1.2 Lower Roof			
			Floor/roof width (ft)	594	594
			Span (ft)	1	1
			Live load (psia)	-	45

			Concrete (psi)	-	3000
			Flyash %	-	average
	4.2 Concrete Precast Double T Roof				
		4.2.1 Upper Roof Overhang			
			Type	Precast Trellis Beam	Precast Double T Roof
			Number of Bays	25	594
			Bay Size (ft)	5.083333333	5.083333333
			Span (ft)	1	1
			Live Load	-	45
			With or W/out Concrete Topping	With	With
		4.2.2 Lower Roof Overhang			
			Type	Precast Trellis Beam	Precast Double T Roof
			Number of Bays	16	16
			Bay Size (ft)	3.833333333	3.833333333
			Span (ft)	0.5	0.5
			Live Load	-	45
			With or W/out Concrete Topping	With	With
5 Stairs					
	5.1 Concrete Footing Foundation				
		5.1.1 Stairs			
			Length (ft)	73	73
			Width (ft)	4.1666	4.1666
			Thickness	6	7.5
			Concrete		9000
			Concrete Flyash %		Avg
			Rebar	5	5
6 Column					
	6.1 Extra Basic Materials				
		6.1.1 Column Core			
			Concrete (yd3) 3000 psi, Average Flyash	4.09	4.09
		6.1.2 Brick Plaster 4"			
			Concrete Brick (Ton)	588.623	588.623

Inputs to Model Single Unit C					
General Description					
	Project Name		Vanier		
	Project Location		UBC		
	Building Life Expectancy		1		
	Building Type		Residential		
	Operating Energy Consumption		-TBA-		
Assembly Group	**Assembly Type**	**Assembly Name**	**Input Fields**	**Input Values**	
				Known/Measured	IE Inputs
1 Foundation					
	1.1 Concrete Slab on Grade				
		1.1.1 - Concrete Slab on Grade 6"			
			Length (ft)	69.275	69.275
			Width (ft)	69.275	69.275
			Thickness (in)	6	8
			Concrete (psi)	3000	3000
			Concrete Flyash %		average
		Define Envelop	Category		Vapour barrier
			Material	Water proof	polyethylene
			Thickness		6 mil
2 Floors				-	
	2.1 Suspended Slab				
		2.1.1 - Suspended Slab 4 1/2"			
			Roof Width (ft)	118.6296759	118.6296759
			Span (ft)	118.6296759	118.6296759
			Concrete (psi)		9000
			Concrete Flyash %		average
			Live Load (psf)		100
		Extra basic Material (ceiling)			
			Envelope Category	Gypsum Board	
			Envelope Material	3/4" Acoustic T. OH Gypsum	5/8" Regular Gypsum Board

			Area	323	323
			Envelope Category	Insulation	323
			Envelope Material	Batt. Fiberglass	Batt. Fiberglass
			Area	323	323
		2.2.2 - Suspended Slab 5"			
			Roof Width (ft)	49.65883607	49.65883607
			Span (ft)	49.65883607	49.65883607
			Concrete (psi)		9000
			Concrete Flyash %		average
			Live Load (psf)		100
		2.2.3 - Suspended Slab 6"			
			Roof Width (ft)	20.4	20.4
			Span (ft)	20.4	20.4
			Concrete (psi)		9000
			Concrete Flyash %		average
			Live Load (psf)		100
3 Custom Wall					
	3.1 Cast In Place				
		3.1.1 - Exterior 10" Concrete			
			Wall Type	Exterior	Exterior
			Length (ft)	345	345
			Height (ft)	8.416666667	8.416666667
			Thickness	10	12
			Concrete		9000
			Concrete Flyash %		Avg
			Reinforcement		6
			Door Type	Aluminum Frame	Aluminum exterior frame 80% glazing
			Door #	4	4
			Status	Inoperable	Inoperable
			Total opening area (ft2)	101.27	101.27
			Number of window units	9	9
			Frame Type	Aluminum Frame	Average
		Opening Types	Glazing Type (double pane glazings)	-	Standard Glazing
		Envelope	Envelope Category	Water proof	Vapour Barrier
			Envelope Material		polyethylene
			Thickness		3 mil
			Envelope Category		Gypsum Board
			Envelope Material	Plaster	Gypsum Regular
			Thickness	5/8	5/8"

			Envelope Category	Insulation	-
			Envelope Material	Styrofoam	Polystyrene Extruded
			Thickness	1"	1"
			Envelope Category	Cladding	-
3.2 Concrete Tilt Up					
	3.2.1 - Exterior 6" Concrete 4" Brick				
			Wall Type	Exterior	Exterior
			Length (ft)	1505	1505
			Height (ft)	8.416666667	8.416666667
			Thickness	6"	5 1/2"
			Concrete		9000
			Concrete Flyash %		Avg
			Rebar	8	6
			Door Type	Aluminum Frame	Aluminum exterior frame 80% glazing
			Door #	3	3
			Status	Inoperable	Inoperable
			Total opening area (ft2)	2175.75	2175.75
			Number of window units	123	123
			Frame Type	Aluminum Frame	Average
		Opening Types	Glazing Type (double pane glazings)	-	Standard Glazing
		Envelope	Envelope Category	Water proof	Vapour Barrier
			Envelope Material		polyethylene
			Thickness		3 mil
			Envelope Category		Gypsum Board
			Envelope Material	Plaster	Gypsum Regular
			Thickness	5/8	5/8"
			Envelope Category	Insulation	-
			Envelope Material	Styrofoam	Polystyrene Extruded
			Thickness	1"	1"
			Envelope Category	Cladding	-
			Envelope Material	Brick	Brick - Concrete
			Thickness	4"	-
	3.2.2 - Interior 6" Concrete				
			Wall Type	Exterior	Exterior
			Length (ft)	1439	1439
			Height (ft)	8.416666667	8.416666667
			Thickness	6"	5 1/2"
			Concrete		9000

			Concrete Flyash %		Avg
			Rebar	8	6
			Door Type	Aluminum Frame	Aluminum exterior frame 80% glazing
			Door #	121	121
		Envelope	Envelope Category	Water proof	Vapour Barrier
			Envelope Material		polyethylene
			Thickness		3 mil
	3.3 Extra Material				
		3.3.1 - Interior 4" Brick Plaster			
			Envelope Material	Brick Plaster 4"	Brick Type 2
			Weight (Tons)	673.2963	673.2963
	3.4 Wood Stud				
		3.4.1 Window Sill			
			Wall Type	Interior	Interior
			Length	29.91	29.91
			Height	29.91	29.91
			Sheathing Type	Plywood	Plywood
			Stud Spacing		25 o.c.
			Stud Type		Green Lumber
			Stud Thickness	2x6	2x7
4 Roof					
	4.1 Concrete Suspended Slab Roof				
		4.1.1 Upper Roof			
			Floor/roof width (ft)	4407	4407
			Span (ft)	1	1
			Live load (psia)	-	45
			Concrete (psi)	-	3000
			Type	Bonded Built Up Roof	Concrete Suspended Slab Roof
			Flyash %	average	
		Define Envelope	Category	Insulation	
			Material	Rigid Insulation	Polystyrene Expanded
			Thickness	1"	1"
		4.1.2 Lower Roof			
			Floor/roof width (ft)	594	594
			Span (ft)	1	1
			Live load (psia)	-	45
			Concrete (psi)	-	3000
			Flyash %	-	average
	4.2 Concrete Precast Double T Roof				

		4.2.1 Upper Roof Overhang			
			Type	Precast Trellis Beam	Precast Double T Roof
			Bay Size (ft)	5.083333333	5.083333333
			Span (ft)	1	1
			Live Load	-	45
			With or W/out Concrete Topping	With	With
		4.2.2 Lower Roof Overhang			
			Type	Precast Trellis Beam	Precast Double T Roof
			Number of Bays	16	16
			Bay Size (ft)	3.833333333	3.833333333
			Span (ft)	0.5	0.5
			Live Load	-	45
			With or W/out Concrete Topping	With	With
5 Stairs					
	5.1 Concrete Footing Foundation				
		5.1.1 Stairs			
			Length (ft)	73	73
			Width (ft)	4.1666	4.1666
			Thickness	6	7.5
			Concrete		9000
			Concrete Flyash %		Avg
			Rebar	5	5
6 Column					
	6.1 Extra Basic Materials				
		6.1.1 Column Core			
			Concrete (yd3) 3000 psi, Average Flyash	4.09	4.09
		6.1.2 Brick Plaster 4"			
			Concrete Brick (Ton)	588.623	588.623

Inputs to Model Whole Building Complex							
General Description							
	Project Name Project Location Building Life Expectancy Building Type Operating Energy Consumption		Vanier UBC 1 Residential -TBA-				
Assembly Group	**Assembly Type**	**Assembly Name**	**Input Fields**	**Input Values**			
				Known/Measured (Unit A x 4)	Known/Measured (Unit B x 2)	Known/Measured (Unit C x 4)	Known/Measured
1 Foundation							
	1.1 Concrete Slab on Grade						
		1.1.1 - Concrete Slab on Grade 6"					
		Define Envelop	Length (ft)	69.27481505	70.328	69.275	1609.471922
			Width (ft)	69.27481505	70.328	69.275	30
			Thickness (in)	8	8	8	8
			Concrete (psi)	3000	3000	3000	3000
			Concrete Flyash %	average	average	average	average
			Category	Vapour barrier	Vapour barrier	Vapour barrier	Vapour barrier
			Material	polyethylene	polyethylene	polyethylene	polyethylene
			Thickness	6 mil	6 mil	6 mil	6 mil

2 Floors							
	2.1 Suspended Slab						
		2.1.1 - Suspended Slab 4 1/2"					
			Roof Width (ft)	118.6296759	118.6296759	118.6296759	4691
			Span (ft)	118.6296759	118.6296759	118.6296759	30
			Concrete (psi)	9000	9000	9000	9000
			Concrete Flyash %	average	average	average	average
			Live Load (psf)	100	100	100	100
		Extra basic Material (ceiling)					
			Envelope Category	Insulation	Insulation	Insulation	Insulation
			Envelope Material	5/8" Regular Gypsum Board	5/8" Regular Gypsum Board	5/8" Regular Gypsum Board	
			Area	323	323	323	3230
			Envelope Category	Insulation	Insulation	Insulation	Insulation
			Envelope Material	Batt. Fiberglass	Batt. Fiberglass	Batt. Fiberglass	Batt. Fiberglass
			Area	323	323	323	3230
		2.2.2 - Suspended Slab 5"					
			Roof Width (ft)	49.65883607	49.65883607	49.65883607	822
			Span (ft)	49.65883607	49.65883607	49.65883607	30
			Concrete (psi)	9000	9000	9000	9000
			Concrete Flyash %	average	average	average	average
			Live Load (psf)	100	100	100	100
		2.2.3 - Suspended Slab 6"					
			Roof Width (ft)	20.39607805	23.73	20.4	148.4955267
			Span (ft)	20.39607805	23.73	20.4	30
			Concrete (psi)	9000	9000	9000	9000
			Concrete Flyash %	average	average	average	average
			Live Load (psf)	100	100	100	100
3 Custom Wall							
	3.1 Cast In Place						
		3.1.1 - Exterior 10" Concrete					

			Wall Type	Exterior	Exterior	Exterior	
			Length (ft)	345	345	345	3450
			Height (ft)	8.41666666 7	8.41666666 7	8.41666666 7	8.41666666 7
			Thickness	12	12	12	12
			Concrete	9000	9000	9000	9000
			Concrete Flyash %	Avg	Avg	Avg	Avg
			Reinforcemen t	6	6	6	6
			Door Type	Aluminum exterior frame 80% glazing	Aluminum exterior frame 80% glazing	Aluminum exterior frame 80% glazing	Aluminum exterior frame 80% glazing
			Door #	4	4	4	40
			Status	Inoperable	Inoperable	Inoperable	Inoperable
			Total opening area (ft2)	101.27	101.27	101.27	1012.7
			Number of window units	9	9	9	90
			Frame Type	Average	Average	Average	Average
		Opening Types	Glazing Type (double pane glazings)	Standard Glazing	Standard Glazing	Standard Glazing	Standard Glazing
		Envelope	Envelope Category	Vapour Barrier	Vapour Barrier	Vapour Barrier	Vapour Barrier
			Envelope Material	polyethylene	polyethylene	polyethylene	polyethylene
			Thickness	3 mil	3 mil	3 mil	3 mil
			Envelope Category	Gypsum Board	Gypsum Board	Gypsum Board	Gypsum Board
			Envelope Material	Gypsum Regular	Gypsum Regular	Gypsum Regular	Gypsum Regular
			Thickness	5/8"	5/8"	5/8"	5/8"
			Envelope Category	-	-	-	-
			Envelope Material	Polystyrene Extruded	Polystyrene Extruded	Polystyrene Extruded	Polystyrene Extruded
			Thickness	1"	1"	1"	1"
			Envelope Category	-	-	-	-
	3.2 Concrete Tilt Up						
		3.2.1 - Exterior 6" Concrete 4" Brick					
			Wall Type	Exterior	Exterior	Exterior	
			Length (ft)	1505	1505	1505	15050
			Height (ft)	8.41666666 7	8.41666666 7	8.41666666 7	8.41666666 7
			Thickness	5 1/2"	5 1/2"	5 1/2"	5 1/2"
			Concrete	9000	9000	9000	9000
			Concrete Flyash %	Avg	Avg	Avg	Avg
			Rebar	6	6	6	6

	Door Type	Aluminum exterior frame 80% glazing	Aluminum exterior frame 80% glazing	Aluminum exterior frame 80% glazing	Aluminum exterior frame 80% glazing
	Door #	3	3	3	30
	Status	Inoperable	Inoperable	Inoperable	Inoperable
	Total opening area (ft2)	2175.745	2175.745	2175.745	21757.45
	Number of window units	123	123	123	1230
	Frame Type	Average	Average	Average	Average
Opening Types	Glazing Type (double pane glazings)	Standard Glazing	Standard Glazing	Standard Glazing	Standard Glazing
Envelope	Envelope Category	Vapour Barrier	Vapour Barrier	Vapour Barrier	Vapour Barrier
	Envelope Material	polyethylene	polyethylene	polyethylene	polyethylene
	Thickness	3 mil	3 mil	3 mil	3 mil
	Envelope Category	Gypsum Board	Gypsum Board	Gypsum Board	Gypsum Board
	Envelope Material	Gypsum Regular	Gypsum Regular	Gypsum Regular	Gypsum Regular
	Thickness	5/8"	5/8"	5/8"	5/8"
	Envelope Category	-	-	-	-
	Envelope Material	Polystyrene Extruded	Polystyrene Extruded	Polystyrene Extruded	Polystyrene Extruded
	Thickness	1"	1"	1"	1"
	Envelope Category	-	-	-	-
	Envelope Material	Brick - Concrete	Brick - Concrete	Brick - Concrete	Brick - Concrete
	Thickness	-	-	-	-
3.2.2 - Interior 6" Concrete					
	Wall Type	Exterior	Exterior	Exterior	Exterior
	Length (ft)	1439	1471.5	1439	14455
	Height (ft)	8.41666666 7	8.41666666 7	8.41666666 7	8.41666666 7
	Thickness	5 1/2"	5 1/2"	5 1/2"	5 1/2"
	Concrete	9000	9000	9000	9000
	Concrete Flyash %	Avg	Avg	Avg	Avg
	Rebar	6	6	6	6
	Door Type	Aluminum exterior frame 80% glazing	Aluminum exterior frame 80% glazing	Aluminum exterior frame 80% glazing	Aluminum exterior frame 80% glazing
	Door #	121	121	121	1210
Envelope	Envelope Category	Vapour Barrier	Vapour Barrier	Vapour Barrier	Vapour Barrier
	Envelope Material	polyethylene	polyethylene	polyethylene	polyethylene
	Thickness	3 mil	3 mil	3 mil	3 mil

	3.3 Extra Material						
		3.3.1 - Interior 4" Brick Plaster					
			Envelope Material	Brick Type 2	Brick Type 2	Brick Type 2	Brick Type 2
			Weight (Tons)	2.313	2.212	2.212	22.524
	3.4 Wood Stud						
		3.4.1 Window Sill					
			Wall Type	Interior	Interior	Interior	
			Length	29.91	29.91	29.91	94.5837248 2
			Height	29.91	29.91	29.91	94.5837248 2
			Sheathing Type	Plywood	Plywood	Plywood	Plywood
			Stud Spacing	25 o.c.	25 o.c.	25 o.c.	25 o.c.
			Stud Type	Green Lumber	Green Lumber	Green Lumber	Green Lumber
			Stud Thickness	2x7	2x7	2x7	2x7
4 Roof							
	4.1 Concrete Suspended Slab Roof						
		4.1.1 Upper Roof					
		Define Envelope	Floor/roof width (ft)	68.16	69.23	68.16	1558.39568 7
			Span (ft)	68.16	69.23	68.16	30
			Live load (psia)	45	45	45	45
			Concrete (psi)	3000	3000	3000	3000
			Type	Concrete Suspended Slab Roof	Concrete Suspended Slab Roof	Concrete Suspended Slab Roof	Concrete Suspended Slab Roof
			Flyash %	Avg	Avg	Avg	Avg
			Category	Insulation	Insulation	Insulation	Insulation
			Material	Polystyrene Expanded	Polystyrene Expanded	Polystyrene Expanded	Polystyrene Expanded
			Thickness	1"	1"	1"	1"
		4.1.2 Lower Roof					
			Floor/roof width (ft)	22.67	22.67	22.67	171.309633 3
			Span (ft)	22.67	22.67	22.67	30
			Live load (psia)	45	45	45	45
			Concrete (psi)	3000	3000	3000	3000
			Flyash %	average	average	average	average
	4.2 Concrete Precast Double T Roof						
		4.2.1 Upper Roof					

		Overhang					
			Type	Precast Double T Roof	Precast Double T Roof	Precast Double T Roof	Precast Double T Roof
			Number of Bays	26	26	26	260
			Bay Size (ft)	5.083333333	5.083333333	5.083333333	5.083333333
			Span (ft)	1	1	1	1
			Live Load	-	-	-	-
			With or W/out Concrete Topping	With	With	With	With
		4.2.2 Lower Roof Overhang					
			Type	Precast Double T Roof	Precast Double T Roof	Precast Double T Roof	Precast Double T Roof
			Number of Bays	16	16	16	160
			Bay Size (ft)	3.833333333	3.833333333	3.833333333	3.833333333
			Span (ft)	0.5	0.5	0.5	0.5
			Live Load	-	-	-	-
			With or W/out Concrete Topping	With	With	With	With
5 Stairs							
	5.1 Concrete Footing Foundation						
		5.1.1 Stairs					
			Length (ft)	73	73	73	730
			Width (ft)	4.1666	4.1666	4.1666	4.1666
			Thickness	6	7.5	7.5	7.5
			Concrete		9000	9000	9000
			Concrete Flyash %		Avg	Avg	Avg
			Rebar	5	5	5	5
6 Column							
	6.1 Extra Basic Materials						
		6.1.1 Column Core					
			Concrete (yd3) 3000 psi, Average Flyash	4.09	4.09	4.09	40.9
		6.1.2 Brick Plaster 4"					
			Concrete Brick (Ton)	673.2963	643.8447	673.2963	6674.0598

Appendix B: EIE Assumptions

1. Foundation

The foundation of Vanier Residence is made of slab on grade. The thickness was rounded from 6” to 8” because of Athena software limitation. This over estimation is expected to be offset by missing concrete in the custom walls.

1.1. Concrete Slab on Grade

1.1.1. Concrete Slab on Grade 6”

Details on Concrete Slab on Grade were modeled using industrial averages due to missing data in concrete Flyash percentage. The thickness of the slab was rounded from 6” to 8” because of Athena software limitations. In this way the over estimation would be more suitable to adjust for overlooked concrete in the building model. A vapour barrier was selected because of waterproof specification. In Athena there is only one viable selection, consequently a 6 mil polyethylene vapour barrier was chosen.

2. Floors

The floors consist of suspended slab with #5 Rebar. Details on flyash percentages were modeled using industrial averages due to missing data. Additionally, the suspended slabs loading and live load were unspecified. As a result, consultation from a civil engineer suggests that these values be maximized, due to weight distribution from the above floors.

2.1. Suspended Slab

2.1.1. Suspended Slab 4 ½”

Details on Suspended Slab were modeled using industrial averages due to missing data in concrete Flyash percentage. The thickness of the slab could not be modeled due to software limitation; in this case the thickness was arbitrary. The loading of the slab was unspecified and maximized at a live load 100psf and concrete

9000psi. Consultations from a civil engineer suggest that these values be maximized, due to weight distribution from the above floors.

2.1.2. Suspended Slab 5”

Details on Suspended Slab were modeled using industrial averages due to missing data in concrete Flyash percentage. The thickness of the slab could not be modeled due to software limitation; in this case the thickness was arbitrary. The loading of the slab was unspecified and maximized at a live load 100psf and concrete 9000psi. Consultations from a civil engineer suggest that these values be maximized, due to weight distribution from the above floors.

2.1.3. Suspended Slab 6”

Details on Suspended Slab were modeled using industrial averages due to missing data in concrete Flyash percentage. The thickness of the slab could not be modeled due to software limitation; in this case the thickness was arbitrary. The loading of the slab was unspecified and maximized at a live load 100psf and concrete 9000psi. Consultations from a civil engineer suggest that these values be maximized, due to weight distribution from the above floors.

3. Custom Wall

For Vanier there are two exterior and two interior walls. The two exterior walls for Vanier were limited by thickness. Correspondingly the 10” thick concrete wall was rounded up to 12,” while concrete part of the concrete brick wall was rounded down from 6” to 5 ½”. The larger area represented by the concrete brick wall is more then enough to create an underestimation in the total concrete volume in the wall, which is then compensated by the overestimation in the foundation.

Lastly an assembly for a 4” brick plaster wall was unavailable in IE. The brick plaster wall was modeled by tons with the plaster omitted.

3.1. Cast in Place

3.1.1. Exterior 10” Concrete

Details on the Exterior 10” Concrete assembly methods were not specified, consequently a choice between concrete block, cast in place and concrete tilt up was needed. In this case it is known that the exterior concrete does no include rebar. Of the available choices, only cast in place does not include a rebar option. The loading of the slab was unspecified and maximized at 9000psi and reinforced at #6 for structural integrity. The thickness of the slab was rounded from 10” to 12” because of Athena software limitations. In this way the over estimation would be more suitable to adjust for overlooked concrete in the building model. Lastly, due to missing data in concrete Flyash percentages, industrial averages were chosen.

Envelope for the wall includes 1” rigid insulation, waterproof and 5/8” plaster. Due to composition similarities the rigid insulation was modeled as polystyrene extruded while the plaster was model as regular gypsum board. A vapour barrier was selected because of waterproof specification. In Athena there is only one viable selection, consequently a 3 mil polyethylene vapour barrier was chosen. Lastly window glazing type (double pane) was chosen as industrial standards due to window detailing deficits.

3.2. Concrete Tilt Up

3.2.1. Exterior 6” Concrete 4” Brick

Details on the Exterior 6” Concrete 4” Brick assembly methods were not specified, consequently a choice between concrete block, cast in place and concrete tilt up was needed. Looking at the individual assembly components, concrete block has a large degree of uncertainty due to its arbitrary values not shown to the user; the only available choices are the rebar number. As such, the concrete tilt up assembly was selected based on the degree of control given to the practitioner. The loading of the wall was unspecified and maximized at 9000psi for structural integrity, while the rebar was reduced from #8 to #6 because of AIE software limitation. The thickness of the slab was rounded from 6” to 5 1/2” due to limitation as well. In this way the under estimation would be compensated by the Exterior 12” (10” actual) Concrete in the building model. Due to missing data in concrete Flyash percentages, industrial averages were chosen. Lastly, a brick envelope was added to model the 4” brick plaster. For this scenario, there are some uncertainties in the arbitrary thickness used by the AIE software.

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Envelope for the wall includes 1” rigid insulation, waterproof and 5/8” plaster. Due to composition similarities the rigid insulation was modeled as polystyrene extruded while the plaster was model as regular gypsum board. A vapour barrier was selected because of waterproof specification. In Athena there is only one viable selection, consequently a 3 mil polyethylene vapour barrier was chosen. Lastly window glazing type (double pane) was chosen as industrial standards due to window detailing deficits.

In AIE the Exterior 6” Concrete 4” Brick wall was separated into ten walls because of software errors. The software error limits the

maximum number of door and window to 100. To adjust for this error the wall was divided into ten sections. In AIE the codename follow by the wall specification represents
- A(area)W(number)D(number). In this way, the codename provides an additional tallying method for the user, to ensure consistency with the takeoff file.

3.2.2. Interior 6” Concrete

Details on the Interior 6” Concrete assembly methods were not specified, consequently a choice between concrete block, cast in place and concrete tilt up was needed. Of the available choices, concrete block and concrete tilt up were available. Looking at the individual assembly components, concrete block has a large degree of uncertainty due to its arbitrary values not shown to the user; the only available choices are the rebar number. As such, the concrete tilt up assembly was selected based on the degree of control given to the practitioner. The loading of the wall was unspecified and maximized at 9000psi for structural integrity, while the rebar was reduced from #8 to #6 because of AIE software limitation. The thickness of the slab was rounded from 6” to 5 1/2” due to limitation as well. In this way the under estimation would be compensated by the Exterior 12” (10” actual) Concrete in the building model. Lastly, due to missing data in concrete Flyash percentages, industrial averages were chosen.

From waterproof specification a vapour barrier had to be selected. In Athena there is only one viable selection, consequently a 3 mil polyethylene vapour barrier was chosen. Lastly, the aluminum frame door was modeled as aluminum exterior frame 80% Glazing because the selection contained one single aluminum frame.

In AIE the Interior 6" Concrete wall was separated into ten walls because of software errors. The software error limits the maximum number of door and window to 100. To adjust for this error the wall was divided into ten sections. In AIE the codename follow by the wall specification represents

- A(area)W(number)D(number). In this way, the codename provides an additional tallying method for the user, to ensure consistency with the takeoff file.

3.3. Extra Basic Material

3.3.1. Interior 4" Brick Plaster

Currently in AIE there is no assembly unit for brick plaster. The brick plaster wall was modeled as brick tons by industrial averages, of 2.7 kg per brick block, while the volume of the brick block obtain from architectural drawings: 2"x 2" x 4". In this way the brick weight was obtained by subdividing the volume of the wall by the volume of the block and multiplying by the weight. Because of a lack of IE assemblies, the plaster specifications were omitted from the modeled wall.

3.4. Wood Stud

3.4.1. Window Sill

Details on the window sill show a wood stud wall assembly. The stud type was rounded from 2 x 6 to 2 x 7. The stud type was chosen as green lumber due to the main use in pre-existing buildings (The Working Forest, 2008). The stud spacing was maximized to reduce loading support, because the integrity of the window sill does not offer structural support.

4. Roof

The roof was modeled as a concrete suspended slab roof. It was assume that the light weight concrete overlay is equivalent to concrete topping. As discussed, this concrete will be compensated by the foundation. The specification for the roof loading was unspecified. Contrary to this, a civil engineer was consulted for the possible loading specification. The loading was minimized because no structural integrity was intended for public use.

The upper and lower roof both contains a precast trellis beam overhang. This beam over hang was superimposed as a roofing assembly due to its similarities to a concrete precast double T roof.

4.1. Concrete Suspended Slab Roof

4.1.1. Upper Roof

Currently in AIE there is no assembly for Bonded Built Up Roof in the envelope category or assembly group. A 6” Concrete layer was seen as roofing material which suggests the use of a suspended concrete slab roof, of which was chosen. The loading of the slab was unspecified and therefore minimized at 3000psi with a live load of 45 psia because no structural integrity was intended for excessive public use.

Envelope for the roof includes 1” rigid insulation or otherwise termed polystyrene expanded. The insulation equivalency is assumed.

4.1.2. Lower Roof

Currently in AIE there is no assembly for Bonded Built Up Roof in the envelope category or assembly group. A 6” Concrete layer was seen as roofing material which suggests the use of a suspended concrete slab roof, of which was chosen. The loading of the slab was unspecified and therefore minimized at 3000psi with a live load of 45 psia because no structural integrity was intended for excessive public use.

Envelope for the roof includes 1" rigid insulation or otherwise termed polystyrene expanded. The insulation equivalency is assumed.

4.2. Concrete Precast Double T Roof

4.2.1. Upper Roof Overhang

The precast trellis beam overhang was superimposed as a roofing assembly due to its similarities to a concrete precast double T roof. For the building model, it is believed that this assumption had to be made due to the overhang significance in material quantity. The loading of the slab was unspecified and therefore minimized at a live load of 45 psia because excessive structural integrity would not be required for weather conditions such as snow. A layer of concrete topping was included to simulate the lightweight concrete specified.

4.2.2. Lower Roof Overhang

The precast trellis beam overhang was superimposed as a roofing assembly due to its similarities to a concrete precast double T roof. For the building model, it is believed that this assumption had to be made due to the overhang significance in material quantity. The loading of the slab was unspecified and therefore minimized at a live load of 45 psia because excessive structural integrity would not be required for weather conditions such as snow. A layer of concrete topping was included to simulate the lightweight concrete specified.

5. Stair

The stairs were modeled as concrete footing foundation for consistency between the residential in UBC. This assumption was made because the stairwell is used only for walking such that no possessions are meant to be located on the stairwells. Consequently, a lower grade concrete can be used; for this case, concrete footing foundation was selected based on the minimal load requirements.

5.1. Footings

5.1.1. Stairs

The complete details of the stairs were not specified, accordingly the load was maximized at 9000psi for structural integrity. Lastly, due to missing data in concrete Flyash percentages, industrial averages were chosen.

6. Column

The 26 brick plaster column was modeled as two individual parts: the column core and the brick exterior. It is noted that the column could be modeled as a tilt-up wall with brick cladding. However, in this scenario it was deemed inappropriate because of the significantly larger amount of brick to concrete ratio that is not seen in standard walls.

6.1. Extra Basic Material

The extra base material was used to model some building components that were not included in IE. One example was acoustic T. OH Gypsum which was model as gypsum board. Another structure was the column supporting the lower roof over hang. The columns were divided into concrete and brick volume. For the brick, this volume was then multiplied into tons in order to be inputted into IE.

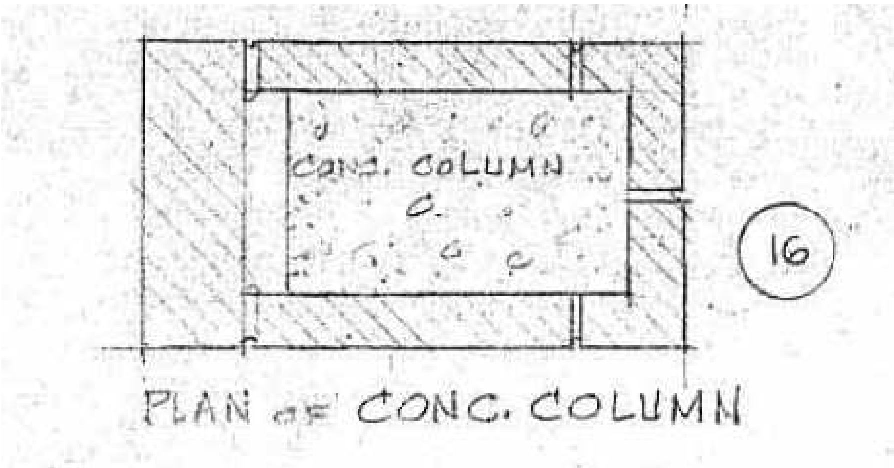

Figure 6: Top View of Brick Plaster Column

6.1.1. Column Core

The concrete in the column core were not specified, as a result averages in Flyash were chosen. The loading was minimized at 3000 psi because the column core is designed to hold the roof. For this case a maximum loading would be inappropriate since the roof does not function as a platform for public use.

6.1.2. 4” Brick Plaster

Currently in AIE there is no assembly unit for brick plaster. The brick plaster wall was modeled as brick tons by industrial averages, of 2.7 kg per brick block, while the volume of the brick block obtain from architectural drawings: 2”x 2” x 6”. The brick plaster was model by a layer by layer basis, three blocks per layer (Refer to Figure 6). In this way the brick weight was obtained by subdividing the height of the bricks by the height of the block and multiplying by the weight. Because of a lack of construction knowledge as well as AIE assemblies, the plaster was omitted from the modeled wall and is not subsidized by standardized gypsum board.

Appendix C: Summary Measures

Vanier Residence Summary Measure	Manufacturing		Construction					
	Material	Trans	Material	Trans	Mat %	Trans %	Overall	Per / ft^2
Primary Energy Consumption MJ	163,074,425	2,828,978.57	3,473,115.25	3,688,638.14	96.23	3.77	173,065,157	288.44
Weighted Resource Use kg	69,520,351.30	91,730.51	159,551.62	83,944.40	99.75	0.25	69,855,578	116.42
Global Warming Potential (kg CO2 eq / kg)	11,818,531.7	4,979.49	234,452.01	6,939.14	99.90	0.099	12,064,902	20.11
Acidification Potential (moles of H+ eq / kg)	2,076,594.13	1,705.58	114,140.58	2,197.044	99.82	0.18	2,194,637.3	3.66
HH Respiratory Effects Potential (kg PM2.5 eq / kg)	30,629.01	2.06	129.33	2.64	99.98	0.015	30763.04	0.052
Eutrophication Potential (kg N eq / kg)	689.047	0.012	3.20E-05	0.0169	99.996	0.00422	689.0762	0.0012
Ozone Depletion Potential (kg CFC-11 eq / kg)	0.01086	2.05E-07	9.77E-12	2.84E-07	99.995	0.005	0.010865	1.81E-08
Smog Potential (kg NOx eq / kg)	34,406.98	38.48	2808.62	49.06	99.77	0.23	37,303.12	0.062

Appendix D: British Columbia Building Code

3) In a *building* that contains *dwelling units* that have more than one *storey*, subject to the requirements of Sentence 3.3.4.2.(3), the floor assemblies, including floors over *basements*, which are entirely contained within these *dwelling units*, shall have a *fire-resistance rating* not less than 1 h but need not be constructed as *fire separations*.

3.2.2.45. Group C, up to 4 Storeys, Sprinklered

1) A *building* classified as Group C is permitted to conform to Sentence (2) provided

a) except as permitted by Sentences 3.2.2.7.(1) and 3.2.2.18.(2), the *building* is *sprinklered* throughout,

b) it is not more than 4 *storeys* in *building height*, and

c) it has a *building area* not more than

i) 7 200 m^2 if 1 *storey* in *building height*,

ii) 3 600 m^2 if 2 *storeys* in *building height*,

iii) 2 400 m^2 if 3 *storeys* in *building height*, or

iv) 1 800 m^2 if 4 *storeys* in *building height*.

2) The *building* referred to in Sentence (1) is permitted to be of *combustible construction* or *noncombustible construction* used singly or in combination, and

a) except as permitted by Sentences (3) and (4), floor assemblies shall be *fire separations* with a *fire-resistance rating* not less than 1 h,

b) *mezzanines* shall have a *fire-resistance rating* not less than 1 h, and

c) *loadbearing* walls, columns and arches shall have a *fire-resistance rating* not less than that required for the supported assembly.

3) In a *building* that contains *dwelling units* that have more than one *storey*, subject to the requirements of Sentence 3.3.4.2.(3), the floor assemblies, including floors over *basements*, which are entirely contained within these *dwelling units*, shall have a *fire-resistance rating* not less than 1 h but need not be constructed as *fire separations*.

4) In a *building* in which there is no *dwelling unit* above another *dwelling unit*, the *fire-resistance rating* for floor assemblies entirely within the *dwelling unit* is waived.

3.2.2.46. Group C, up to 3 Storeys, Increased Area

1) A *building* classified as Group C is permitted to conform to Sentence (2) provided

a) it is not more than 3 *storeys* in *building height*, and

b) it has a *building area* not more than the value in Table 3.2.2.46.

Table 3.2.2.46.
Maximum Building Area, Group C, up to 3 Storeys, Increased Area
Forming Part of Sentence 3.2.2.46.(1)

No. of *Storeys*	Maximum Area, m^2		
	Facing 1 *Street*	Facing 2 *Streets*	Facing 3 *Streets*
1	2 400	3 000	3 600
2	1 200	1 500	1 800
3	800	1 000	1 200

2) The *building* referred to in Sentence (1) is permitted to be of *combustible construction* or *noncombustible construction* used singly or in combination, and

a) except as permitted by Sentences (3) and (4), floor assemblies shall be *fire separations* with a *fire-resistance rating* not less than 1 h,

b) *mezzanines* shall have a *fire-resistance rating* not less than 1 h,

c) roof assemblies shall have a *fire-resistance rating* not less than 1 h, and

d) *loadbearing* walls, columns, and arches shall have a *fire-resistance rating* not less than that required for the supported assembly.

3) In a *building* that contains *dwelling units* that have more than one *storey*, subject to the requirements of Sentence 3.3.4.2.(3), the floor assemblies, including floors over *basements*, which are entirely contained within these *dwelling units*, shall have a *fire-resistance rating* not less than 1 h but need not be constructed as *fire separations*.

4) In a *building* in which there is no *dwelling unit* above another *dwelling unit*, the *fire-resistance rating* for floor assemblies entirely within the *dwelling unit* is waived.

3.2.2.47. Group C, up to 3 Storeys

1) A *building* classified as Group C is permitted to conform to Sentence (2) provided

a) it is not more than 3 *storeys* in *building height*, and

b) it has a *building area* not more than the value in Table 3.2.2.47.

Table 3.2.2.47.
Maximum Building Area, Group C, up to 3 Storeys
Forming Part of Sentence 3.2.2.47.(1)

No. of *Storeys*	Maximum Area, m^2		
	Facing 1 *Street*	Facing 2 *Streets*	Facing 3 *Streets*
1	1 800	2 250	2 700
2	900	1 125	1 350
3	600	750	900

2) The *building* referred to in Sentence (1) is permitted to be of *combustible construction* or *noncombustible construction* used singly or in combination, and

a) except as permitted by Sentences (3) and (4), floor assemblies shall be *fire separations* with a *fire-resistance rating* not less than 45 min,

b) *mezzanines* shall have, if of *combustible construction*, a *fire-resistance rating* not less than 45 min, and

c) *loadbearing* walls, columns and arches shall have a *fire-resistance rating* not less than that required for the supported assembly.

3) In a *building* that contains *dwelling units* that have more than one *storey*, subject to the requirements of Sentence 3.3.4.2.(3), the floor assemblies, including floors over *basements*, which are entirely contained within these *dwelling units*, shall have a *fire-resistance rating* not less than 45 min but need not be constructed as *fire separations*.

4) In a *building* in which there is no *dwelling unit* above another *dwelling unit*, the *fire-resistance rating* for floor assemblies entirely within the *dwelling unit* is waived.

3.2.2.48. Group C, up to 3 Storeys, Sprinklered

1) A *building* classified as Group C is permitted to conform to Sentence (2) provided

Appendix E: Concrete Block Versus Wood

Concrete	Manufacturing			Construction			Maintenance			End - Of - Life			Operating Energy		Total Effects
	Material	Transport-ation	**Total**	Material	Transport-ation	**Total**	Material	Transport-ation	**Total**	Material	Transport-ation	Total	Annual	**Total**	
Primary Energy Consumption MJ	5851.72	42.65	5894.4	124.89	307.14	432.03	124.89	0.00	124.89	13.65	85.36	99.01	0.00	0.00	6550.31
Weighted Resource Use kg	1168.41	1.11	1169.5	5.74	6.99	12.73	5.74	0.00	5.74	0.31	1.94	2.25	0.00	0.00	1190.23
Global Warming Potential (kg CO2 eq / kg)	560.35	0.08	560.4	8.71	0.59	9.31	8.71	0.00	8.71	0.89	0.16	1.05	0.00	0.00	579.50
Acidification Potential (moles of H+ eq / kg)	115.86	0.02	115.9	3.77	0.19	3.96	3.77	0.00	3.77	0.05	0.05	0.10	0.00	0.00	123.72
HH Respiratory Effects Potential (kg PM2.5 eq / kg)	0.94	0.00	0.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95
Eutrophication Potential (kg N eq / kg)	0.02	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Ozone Depletion Potential (kg CFC-11 eq / kg)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Smog Potential (kg NOx eq / kg)	0.95	0.00	0.95	0.12	0.00	0.12	0.12	0.00	0.12	0.00	0.00	0.00	0.00	0.00	1.20

Wood	Manufacturing			Construction			Maintenance			End - Of - Life			Operating Energ	
	Material	Transportation	Total	Material	Transport-ation	Total	Material	Transport-ation	Total	Material	Transport-ation	Total	Annual	Total
Primary Energy Consumption MJ	765.84	34.53	800.38	54.81	222.43	277.23	54.81	0.00	54.81	0.12	5.97	6.09	0.00	0.0
Weighted Resource Use kg	558.45	0.79	559.24	6.16	5.06	11.22	6.16	0.00	6.16	0.00	0.14	0.14	0.00	0.0
Global Warming Potential (kg CO2 eq / kg)	24.13	0.07	24.19	4.94	0.27	5.22	4.94	0.00	4.94	0.01	0.01	0.02	0.00	0.0
Acidification Potential (moles of H+ eq / kg)	6.95	0.02	6.97	2.01	0.09	2.10	2.01	0.00	2.01	0.00	0.00	0.00	0.00	0.0
HH Respiratory Effects Potential (kg PM2.5 eq / kg)	0.07	0.00	0.07	0.01	0.00	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.0
Eutrophication Potential (kg N eq / kg)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
Ozone Depletion Potential (kg CFC-11 eq/ kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
Smog Potential (kg NOx eq / kg)	0.10	0.00	0.10	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0

Appendix F: Energy Modeling

CURRENT

		Temperature			Energy Loss		
Month	Days in Month	Historical Avg. (deg C)	Historical Avg. (deg F)	Temp.Diff. (deg F)	(BTU used per month)	(kWh used per month)	(MJ used per month)
Jan	31	3.6	38.48	29.52	47,065,254.70	13,793.47	49,656.47
Feb	28	4.9	40.82	27.18	39,140,813.70	11,471.04	41,295.75
Mar	31	6.6	43.88	24.12	38,455,756.89	11,270.27	40,572.97
Apr	30	9.1	48.38	19.62	30,272,105.21	8,871.88	31,938.76
May	31	12.3	54.14	13.86	22,097,711.05	6,476.20	23,314.32
Jun	30	14.7	58.46	9.54	14,719,464.00	4,313.85	15,529.86
Jul	31	16.9	62.42	5.58	8,896,481.07	2,607.30	9,386.28
Aug	31	17.1	62.78	5.22	8,322,514.55	2,439.09	8,780.72
Sep	30	14.5	58.1	9.90	15,274,915.47	4,476.64	16,115.89
Oct	31	10.3	50.54	17.46	27,837,376.26	8,158.33	29,369.99
Nov	30	6.1	42.98	25.02	38,603,877.28	11,313.68	40,729.25
Dec	31	3.8	38.84	29.16	46,491,288.18	13,625.25	49,050.91
Annual	30	10.0	49.99	18.02	337,177,558.36	98,816.99	355,741.17

IMPROVED

		Temperature			Energy Loss		
Month	Days in Month	Historical Avg. (deg C)	Historical Avg. (deg F)	Temp.Diff. (deg F)	(BTU used per month)	(kWh used per month)	(MJ used per month)
Jan	31	3.6	38.48	29.52	23,388,263.95	6,854.42	24,675.93
Feb	28	4.9	40.82	27.18	19,450,350.12	5,700.34	20,521.21
Mar	31	6.6	43.88	24.12	19,109,922.99	5,600.57	20,162.04
Apr	30	9.1	48.38	19.62	15,043,198.88	4,408.73	15,871.42
May	31	12.3	54.14	13.86	10,981,075.15	3,218.24	11,585.65
Jun	30	14.7	58.46	9.54	7,314,582.94	2,143.69	7,717.29
Jul	31	16.9	62.42	5.58	4,420,952.33	1,295.65	4,664.35
Aug	31	17.1	62.78	5.22	4,135,729.60	1,212.06	4,363.43
Sep	30	14.5	58.1	9.90	7,590,604.94	2,224.59	8,008.51
Oct	31	10.3	50.54	17.46	13,833,302.46	4,054.14	14,594.91
Nov	30	6.1	42.98	25.02	19,183,528.85	5,622.14	20,239.70
Dec	31	3.8	38.84	29.16	23,103,041.22	6,770.83	24,375.00
Annual	30	10.0	49.99	18.02	167,554,553.44	49,105.39	176,779.42

Annual Energy Usage (MJ)					
Year	Current'	Improved'	Year	Current'	Improved'
	173060.49	175546.65	40	14229.65	9557.34
0	0.00	2486.16	41	14585.39	9734.12
1	355.74	2662.94	42	14941.13	9910.90
2	711.48	2839.72	43	15296.87	10087.68
3	1067.22	3016.50	44	15652.61	10264.46
4	1422.96	3193.28	45	16008.35	10441.23
5	1778.71	3370.06	46	16364.09	10618.01
6	2134.45	3546.84	47	16719.84	10794.79
7	2490.19	3723.62	48	17075.58	10971.57
8	2845.93	3900.40	49	17431.32	11148.35
9	3201.67	4077.18	50	17787.06	11325.13
10	3557.41	4253.96	51	18142.80	11501.91
11	3913.15	4430.73	52	18498.54	11678.69
12	4268.89	4607.51	53	18854.28	11855.47
13	4624.64	4784.29	54	19210.02	12032.25
14	4980.38	4961.07	55	19565.76	12209.03
15	5336.12	5137.85	56	19921.51	12385.81
16	5691.86	5314.63	57	20277.25	12562.59
17	6047.60	5491.41	58	20632.99	12739.37
18	6403.34	5668.19	59	20988.73	12916.15
19	6759.08	5844.97	60	21344.47	13092.93
20	7114.82	6021.75	61	21700.21	13269.71
21	7470.56	6198.53	62	22055.95	13446.49
22	7826.31	6375.31	63	22411.69	13623.26
23	8182.05	6552.09	64	22767.44	13800.04
24	8537.79	6728.87	65	23123.18	13976.82
25	8893.53	6905.65	66	23478.92	14153.60
26	9249.27	7082.43	67	23834.66	14330.38
27	9605.01	7259.21	68	24190.40	14507.16
28	9960.75	7435.98	69	24546.14	14683.94
29	10316.49	7612.76	70	24901.88	14860.72
30	10672.24	7789.54	71	25257.62	15037.50
31	11027.98	7966.32	72	25613.36	15214.28
32	11383.72	8143.10	73	25969.11	15391.06
33	11739.46	8319.88	74	26324.85	15567.84
34	12095.20	8496.66	75	26680.59	15744.62
35	12450.94	8673.44	76	27036.33	15921.40
36	12806.68	8850.22	77	27392.07	16098.18
37	13162.42	9027.00	78	27747.81	16274.96
38	13518.16	9203.78	79	28103.55	16451.74
39	13873.91	9380.56	80	28459.29	16628.51