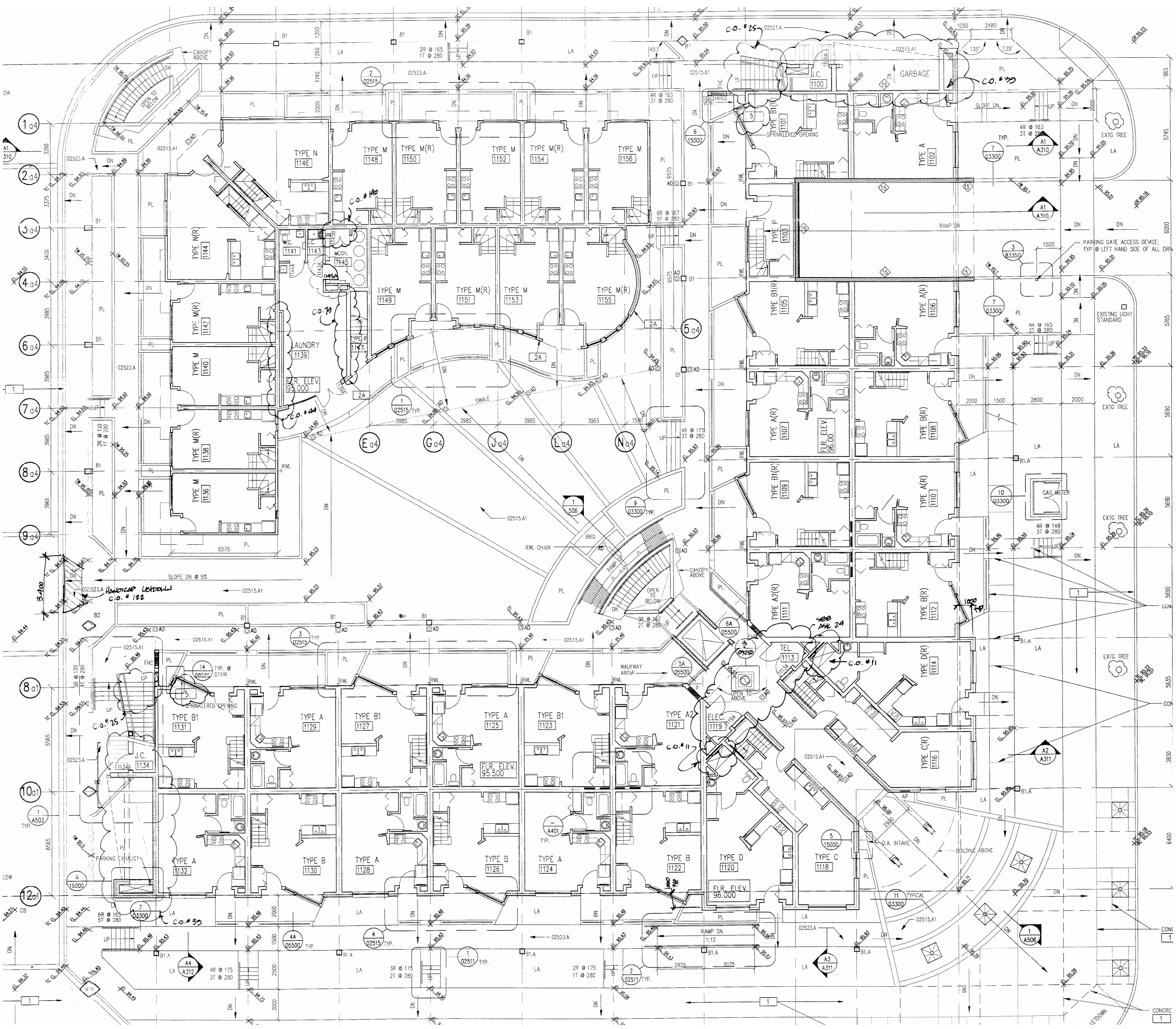
Life Cycle Analysis of UBC Buildings:

The Thunderbird Residences



<u>Source</u>: Drawing 780-06-012, Thunderbird Residences

Submitted to Mr. Robert Sianchuk

CIVL 498C

The University of British Columbia

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By Jesse Wiebe

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ABSTRACT

A comprehensive case study life cycle analysis ("LCA") was performed on the Thunderbird residence buildings A1 and A4, located at the University of British Columbia. Buildings A1 and A4 comprised one of the five blocks that are defined as the Thunderbird residences ("the residences"). The LCA characteristics of buildings A1 and A4 were used as models to estimate the other four blocks of the residences, thus achieving an LCA for the whole site defined as the Thunderbird residences. The residence's five residential blocks situate ten low-rise rental apartment buildings, with an approximate total gross floor area of 610,000 SF.

This analysis was conducted using cradle to gate LCA boundary conditions, which included the life cycle stages "manufacturing" and "construction". The primary energy consumption over the residences life cycle is an estimated 3.0 x 10^8 MJ, or 496 MJ/ft^2. It was found that the majority of the energy consumption occurred in the manufacturing stage of the residences life, accounting for an approximate 90% of the total primary energy consumption.

All of the IE summary measures have been included in this study, ie. energy consumption, acidification potential, global warming potential, Human Health Criteria Air-Mobile, ozone depletion potential, smog potential, eutrophication potential and weighted resource use.

This report also explores the use of a material-type sensitivity analysis and building energy performance modeling, to observe their benefit in current and future construction designs.

LIST OF ABBREVIATIONS

BoM	bill of materials
CF	cubic foot
CFC	chlorofluorocarbon
CO_2	carbon dioxide
IE	environmental impact estimator
Eq	Equivalents
HH	human health
Kg	kilogram
kWh	Kilowatt hour
LCA	life cycle analysis
LCI	life cycle inventory
LCIA	life cycle impact assessment
LF	linear foot
MJ	mega Joules
N	nitrogen
NO_x	nitrogen oxide
PM25	particulate matter less than 2.5 microns in diameter
SF	square foot
XBM	extra basic materials

1.0 INTRODUCTION

This report presents the Thunderbird residences as the focus of a life cycle analysis. Located at 6335 Thunderbird Crescent, the Thunderbird residences are comprised of five nearly identical blocks containing two buildings each.

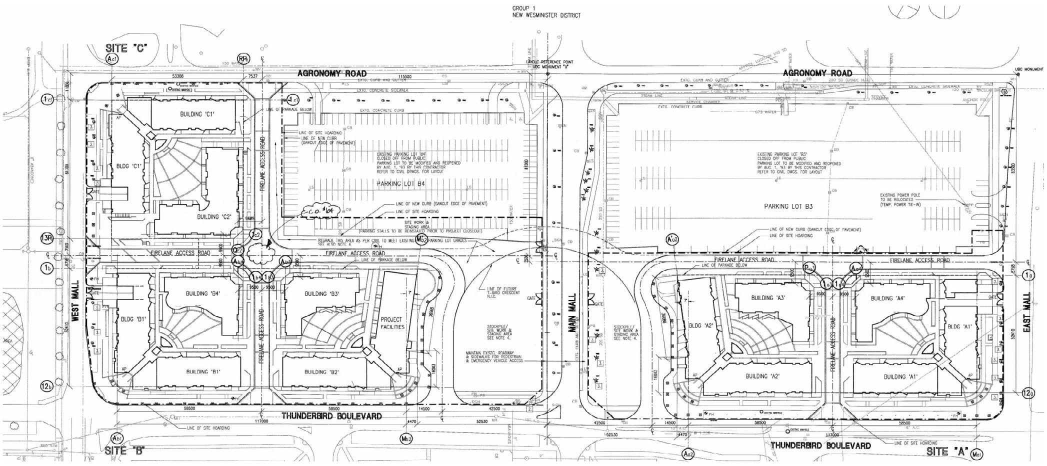


Figure 1. Drawing 780-06-003, Thunderbird Residences – Approximate layout. For illustrative purposes only, not as-built

The residences were built in 1995, consisting of 403 studio, one, two, and four bedroom units, accommodating an approximate 450-500 students. The ten buildings that encompass the Thunderbird residences are named as follows: A1, A2, A3, A4, B1, B2, B3, B4, C1, and C2. The buildings A1 and A4, which formed the detailed portion of this analysis, were four and two storeys, respectively, and irregular in shape.

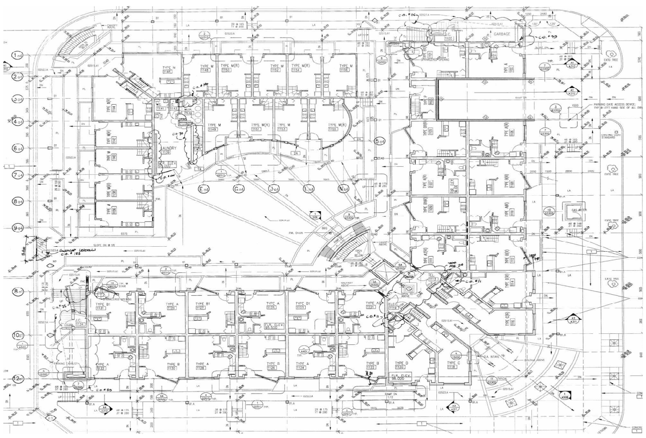


Figure 2. Drawing 780-06-012, Buildings A1 & A4

The underground parkade spans below buildings A1, A4, and the center courtyard. This parkade was included with buildings A1 and A4 in this analysis. The residences were constructed using a variety of materials. These construction materials and general building data are listed in the following table:

Table 1. Thunderbird Residences: Building data, All Buildings

Building Systems	Structural Characteristics
Structure	Parkade: reinforced concrete columns and beams; ground floor, second, third and fourth floor: hollow structural steel, parallell strand lumber, and built-up lumber columns and beams, of varying size
Floor System	Parkade: reinforced concrete slab on grade 4” thickness, ¼” vapor barrier; ground floor: reinforced concrete suspended slab 6” thickness, 4” rigid insulation, ¼” vapor barrier; second, third and fourth floor: insulated 12” web wood truss-joist system, 5/8” plywood subfloor, and concrete topping
Exterior Walls	Stucco wall: stucco on metal mesh, 2”x6” wood stud backing, with 1/8” vapor barrier, plywood, and 5/8” gypsum board sheathing, 4” fiberglass batt insulation; brick wall: clay brick (type 1) with 2”x6” wood stud backing, 1/8” vapor barrier, plywood, and gypsum board sheathing, 4” fiberglass batt insulation
Interior Walls	Demising walls between suites: two rows of wood studs 2"x4", ½” gypsum board sheathing both sides, 4” fiberglass batt insulation; typical walls within suites: one row of wood studs 2"x4", ½” gypsum board sheathing both sides, 2” fiberglass batt insulation
Windows	Standard glazing (double panes, 1/2” airspace)
Roof System	Four story building: 12" web truss joist system, built-up torch down roof cover, 8" fiberglass batt insulation, 1/2" plywood, 2 layers 5/8" gypsum board; two story roof: steel deck, membrane roof sheathing, 2”x10” kiln-dried soft-wood lumber joists, 8" fiberglass batt insulation, 1/2" plywood, 2 layers 5/8" gypsum board; parkade roof (below courtyard only) 6” concrete
Energy	8,878,424 kWh Annual usage, hydro-electric power (used for heat, lights, appliances, etc)

2.0 GOAL OF STUDY

This life cycle analysis (LCA) of the Thunderbird residences ("the residences") 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 residences 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 residences. An exemplary application of these references are in the assessment of potential future performance upgrades to the structure and envelope of the residences. 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 LCA of the residences 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 audience of this LCA study are those involved in building development related policy making at UBC, such as the Sustainability Office, who are involved in creating policies and frameworks for sustainable development on campus. Other potential audiences include developers, architects, engineers and building owners involved in design planning, as well as external organizations such as governments, private industry and other universities whom may want to learn more or become engaged in performing similar LCA studies within their organizations.

3.0 SCOPE OF STUDY

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

3.1 Tools, methodology and data

Two main software tools are to be utilized to complete this LCA study; On-Center's On-Screen Take-Off 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, On-Screen Take-Off version 3.6.2.25 is used, which is a software tool designed to perform material takeoffs with increased accuracy and speed in order to enhance the bidding capacity of its users. Using imported digital plans, the program simplifies the calculation and measurement of the takeoff process, while reducing the error associated with these two activities. The measurements generated are formatted into the inputs required for the IE building LCA software to complete the takeoff process. These formatted inputs as well as their associated assumptions can be viewed in Annexes A and B respectively.

Using the formatted takeoff data, version 4.0.51 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 Vancouver region as a multi-unit residential rental 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 residences 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 residences, 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 residences. 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 as-built architectural and structural drawings from when the residences were initially constructed in 1995. 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 finishes (floor, wall, ceiling, etc), electrical aspects, HVAC system, 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 limitations will be discussed further as they emerge in the Building Model section and, as previously mentioned, all specific input related assumptions are contained in the Input Assumptions document in Annex B.

4.0 BUILDING MODEL

4.1 BUILDING TAKE-OFFS

Material quantity takeoffs were conducted using three On-Screen Take-Off ("OS") conditions. These conditions are: linear, area, and count conditions. A number of materials were not included in this analysis due to limitations of material selection in the IE, and to minimize sources of uncertainty. Materials that were not included in this analysis are: floor, ceiling and wall finishes; heating, cooling, plumbing, electrical, elevators and fire protection systems; furnishings, appliances and chattels; and exterior improvements including stairs and courtyard fixtures.

The following section describes the take-off methodology used per building component.

4.1.1 Foundations

- Spread footing details were obtained through use of the count condition, and then applied to the specifications furnished in the structural drawing set
- The perimeter footing quantities were obtained using the linear condition, and then again applied to the structural drawing set specifications
- The concrete slab on grade material was quantified using the area condition

Foundations General Assumptions & Methodology

- Due to available inputs in the IE, length, width and thickness measurements inputted into the program were modified to reflect actual measured volume, not actual length, width, and thickness. The IE then takes this input information and then relates it back into a volume, therefore, there is no error associated with this form of data input
- Concrete flyash percentage was assumed as 'average' in the IE model.

- Concrete strength was rounded up, when not available in the IE (eg. 3500Psi concrete not available, therefore 4000Psi concrete was used)

4.1.2 Columns and Beams

- Column and beam quantities were determined using the OS count condition for each different type of column and beam

Columns and Beams General Assumptions & Methodology

- Nomenclature: Built-up lumber columns = BU lumber columns
- Bay sizes, supported spans, and column types varied greatly throughout the structure without a grid pattern layout. Span and width dimensions were necessary inputs for the IE. In this case 20’ Span and 20’ bay widths are considered representative of the column and beam layout based on various averaged distances.
- No structural drawings displaying columns and beams for smaller building A4 were provided. As resolved through discussions with the project director, columns and beams were proportioned to A4 from the building A1 analysis based on building area proportions.

4.1.3 Floor System

- Floor area quantities were found using various OS area conditions for different building levels, thicknesses were determined from structural drawing specifications

Floor System General Assumptions & Methodology

- Span & width were inputted into the IE to reflect actual measured area, not actual span and width.

- Concrete topping of applicable floors was added in Extra Basic Materials

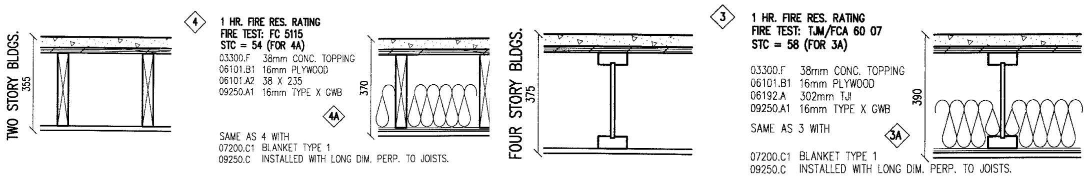


Figure 3. Drawing 780-06-002, Typical Combustible Floor Construction

4.1.4 Roof System

- Roof system material quantities were determined using the OS area conditions, and then combined with details from the structural drawing specifications to obtain total material amounts

Roof System General Assumptions & Methodology

- Span & width inputted into the IE to reflect actual measured area, not actual span and width.
- Two storey roof applies to building A4, as the majority of this building is two storey
- Four storey roof applies to building A1, as the majority of this building is four storey

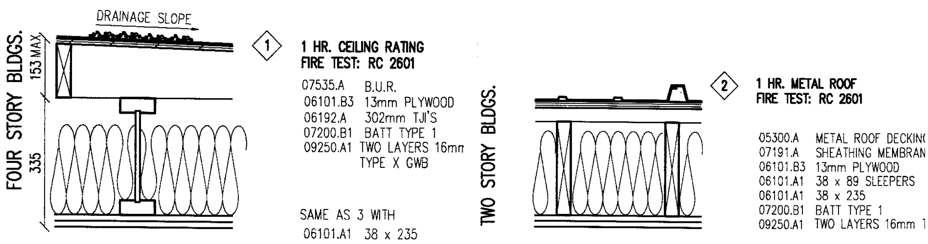


Figure 4. Drawing 780-06-002, Typical combustible roof/ceiling construction

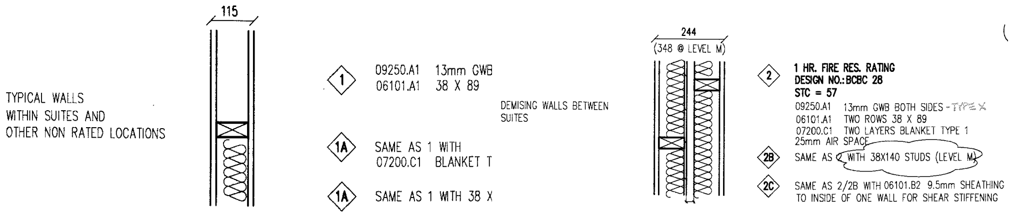
4.1.5 Interior and Exterior Walls

- Material quantities were determined using the OS linear condition, and then given depth and height through the use of elevation drawings, differing floor elevation datum points, and the use of sectional structural specification drawings
- Door quantities were found using the OS count condition

Interior and Exterior Walls General Assumptions & Methodology

- In the build of the IE software that we were using (ie. build 51), a known issue was that windows and doors were limited to a maximum of 100 (each) per wall section. Many wall sections had greater than 100 doors/windows, therefore copies of these walls were made in the IE to accommodate this door and window restriction.
- Standard glazing was assumed for all windows, reflecting construction of 1995
- Windows were modeled based on two typical sample wall areas >1000 ft^2. The OS area and count conditions were used to determine the average amount of window fenestration per unit wall area. This method was made possible by the uniformity of fenestration throughout.
- Stud spacing was not detailed in the drawings, and was assumed to be that of typical residential wall construction 16” o/c.
- Drawings state floor sheathing thickness, but not type. Sheathing type is assumed to be plywood.
- For stucco walls, stucco area was percentaged in certain areas to apply to areas lacking elevation drawings. This assumption was made in conjunction with an on-site inspection to confirm percentage break-ups.

- For brick walls the clay brick is assumed to be best represented by concrete brick in model.



4.1.6 Extra Basic Materials ("XBM's")

- Extra Basic Materials were quantified using the OS area condition and then applied to the structural drawing specifications

4.1.7 Miscellaneous General Assumptions & Methodology

- The Commonsblock building was modeled as a residence building due to the fact that it was not included with the sample site 'A'. It is, however, constructed in the same way as all the other residences, differing only in interior layout. For this building, this analysis will slightly over-estimate the amount of interior partitioning per square foot. The Commonsblock building is different from the residences in that it contains a fitness room, activity room and a music practice room.
- Due to symmetry of buildings, some quantities were taken off in half measures, and have been noted in OS with "half" in the given name of the take-off

4.1.8 Challenges in Take-offs

- Bugs in the IE build used (ie. 51), made inputs of walls, windows, and doors very complicated
- There was a challenge in creating a labeling system that correlated with all the other programs used, and left an easy to follow trail of calculations. This became increasingly challenging with data that would be provided by OS in a certain way, and then required another form of input in the IE.

- In some cases it was difficult to read small print on drawings.

- ❖ For more details on the numerical inputs used in the IE, please refer to the 'Impact Estimator Input Tables' (in Appendix A).

- ❖ For more detailed descriptions and calculations corresponding to the assumptions made, please refer to the 'Impact Estimator Input Assumptions Document' (in Appendix B).

4.2 BILL OF MATERIALS

The Bill of Materials table shows the total amount of all building materials resulting from the construction of the Thunderbird residences (five blocks) in SI units (Athena IE 4.0.51).

Table 2. Bill of Materials

Material	Quantity	Unit
#15 Organic Felt	15,064	m2
1/2" Regular Gypsum Board	51,661	m2
3 mil Polyethylene	13,870	m2
5/8" Regular Gypsum Board	41,301	m2
6 mil Polyethylene	42,512	m2
Aluminium	137	Tonnes
Ballast (aggregate stone)	94,232	Kg
Batt. Fiberglass	158,600	m2 (25mm)
Blown Cellulose	5,569	m2 (25mm)
Cold Rolled Sheet	1	Tonnes
Concrete 30 MPa (flyash av)	29,087	m3
Concrete Brick	4,895	m2
EPDM membrane	9,096	Kg
Expanded Polystyrene	34,465	m2 (25mm)
Galvanized Sheet	71	Tonnes
Hollow Structural Steel	47	Tonnes
Joint Compound	93	Tonnes
Laminated Veneer Lumber	752	m3
Large Dimension Softwood Lumber, kiln-dried	180	m3
Mortar	91	m3
Nails	22	Tonnes
Paper Tape	1	Tonnes
Rebar, Rod, Light Sections	9,001	Tonnes
Roofing Asphalt	60,377	Kg
Screws Nuts & Bolts	0	Tonnes
Small Dimension Softwood Lumber, Green	4	m3
Small Dimension Softwood Lumber, kiln-dried	1,931	m3
Softwood Plywood	101,981	m2 (9mm)
Solvent Based Alkyd Paint	283	L
Standard Glazing	9,604	m2
Stucco over metal mesh	1,557	m2
Type III Glass Felt	20,462	m2
Water Based Latex Paint	893	L
Welded Wire Mesh / Ladder Wire	29	Tonnes

4.2.1 Discussion of five major contributors to the Bill of Materials

In viewing the bill of materials (¨BoM¨), five significant material classes are noticed: concrete, lumber, glazing, gypsum board and fiberglass batt insulation. One challenge in comparing the values provided by the BoM is the difference in relative units, and the differences in relative properties of the materials (eg. weight strength ratio, density, etc).

4.2.1.1 Concrete 30 MPa (flyash av)

30 Mpa concrete is found in many of the residence´s assemblies, and is the most used material on a per kilogram basis. The amount of volume in all of the residences measures 29,087m^3. The majority of the concrete in the residences is actually 25MPa concrete, however, the compressive strength was rounded up to 30 MPa to match the available input selection in the IE. This rounding up to 30MPa will have a slight impact on the summary measures, due to the requirement of more energy inputs, and the subsequent higher amounts of emissions. In the parkade area, slab bands were modeled as beams for lack of other input options. It seems that the IE will underestimate the amount of concrete actually in these slab bands due to their size much larger than an average beam. This is difficult to determine without knowing how the IE models beam takeoffs. In the case of the slab bands being under estimated, the BoM will be slightly under in the amount of actual concrete in the residences. The assemblies containing the most concrete are extra basic materials (concrete floor topping), foundations, and roofs (parkade roof below courtyard).

4.2.1.2 Small Dimension Softwood Lumber, kiln-dried

Found in all the walls as stud systems, roofs as joist systems, columns and beams as built-up members, and stairs as treads and risers, small dimension softwood lumber, (kiln-dried) totals at 1,931$m^3$for the residences. In the case where built-up beams and columns are consisting of three 2”x 6” softwood members, then the IE will have the correct input. This is the case for the majority of built-up beams and columns. There are a few cases, however, where the built-up beams and columns consist of four 2”x 6” members. In this case the IE will have underestimated this entry in the BoM. This underestimation is seemingly minor as most built-columns and beams conform to the IE’s model.

4.2.1.3 Standard Glazing

Applied to every window in the residences, the standard glazing IE output resulted with an area of 9,604m^2. Known issues in the IE build 51 existed for the wall, window, and door inputs. By creating multiply sections of each type wall, the BoM was corrected and this value reflects the actual amount of window glazing in the residences.

4.2.1.4 Regular Gypsum Board 1/2"

Gypsum board was applied in varying thicknesses in the wall, roof, and floor assemblies. The amount of ½” gypsum board in the residences amounted to 51,661m^2. This amount had no known sources of take off and input errors.

4.2.1.5 Fiberglass Batt

Fiberglass batt was applied in varying thicknesses in the wall, roof, and floor assemblies. The amount of Fiberglass batt in the residences amounted to 158,600 m2 (per 25mm thickness). Batt insulation had to be determined qualitatively in some areas, by looking at sectional drawings where the drawings were not dimensioned

5.0 SUMMARY MEASURES

The summary measures represent potential environment effects, and are also known as “impact assessment categories” or just “impacts”. Once the BoM was generated by the IE, a life cycle inventory for the Thunderbird residences was calculated. A subsequent set of summary impact indicators were then determined by the IE through the use of the US EPA’s Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts “TRACI”. The individual summary measures are described in more detail in section 5.3

It should be noted that our analysis did not take into account regional (Vancouver) factors when determining the summary measures. The summary measures used by the IE are a non-regionalized version of TRACI for the United States and Canada.

Table 3. Thunderbird Residences Summary Measures By Life Cycle Stage

Summary Measures By Life Cycle Stage							
Classification	**Manufacturing ("M")**			**Construction ("C")**			**Total M & C**
	Material	**Transport-ation**	**Total**	**Material**	**Transport-ation**	**Total**	
Primary Energy Consumption MJ	269,179,045	5,634,668	274,813,713	9,970,736	18,358,105	28,328,841	**303,142,554**
Weighted Resource Use kg	110,737,387	165,984	110,903,372	457,582	417,788	875,370	**111,778,742**
Global Warming Potential (kg CO2 eq / kg)	16,634,932	10,113	16,645,046	696,955	33,184	730,139	**17,375,185**
Acidification Potential (moles of H+ eq / kg)	3,441,963	3,387	3,445,350	277,207	10,575	287,782	**3,733,133**
HH Respiratory Effects Potential (kg PM2.5 eq / kg)	45,076	4	45,080	311	13	324	**45,404**
Eutrophication Potential (kg N eq / kg)	1,586	0	1,586	0	0	0	**1,587**
Ozone Depletion Potential (kg CFC-11 eq / kg)	0	0	0	0	0	0	**0**
Smog Potential (kg NOx eq / kg)	51,344	76	51,420	6,864	236	7,101	**58,521**

5.1 SUMMARY MEASURES BY LIFE CYCLE STAGE DESCRIPTION

The above table summarizes the life cycle effects over two stages of the material's life, the manufacturing and construction stages. The manufacturing stage includes: resource extraction, resource transportation and the manufacturing of specific materials, products or building materials. The construction stage includes: product transportation from the place of manufacture to the construction site.

From this table it is observed that the major environmental impacts occur in the manufacturing stage of the construction materials. In comparison to manufacturing, the construction stage does not include many energy intensive processes, therefore it its environmental impact is less. It should be noted, however, that the IE model does not include summary measure allowances for the heavy equipment used on-site during construction (eg. Cranes, excavators, loaders, etc), which would increase the impact of the construction stage.

It is difficult to determine which summary measure environmental impacts are dominant because of the difference in units among these measures. It is also up to the LCA practitioner to determine which impacts are most sensitive for the subject region, which has not formed a part of this study.

Table 4. Thunderbird Residences Summary Measures By Assembly Group

Summary Measures By Assembly Group							
Material ID	Foundations	Walls	Beams and Columns	Roofs	Floors	Extra Basic Mater	**Total**
Primary Energy Consumption MJ	13,340,483	47,994,905	23,493,246	200,458,217	19,865,780	1,374,113	**306,526,743**
Weighted Resource Use kg	13,585,006	15,856,050	7,565,830	54,646,772	13,448,504	1,890,751	**106,992,913**
Global Warming Potential (kg CO2 eq / kg)	3,138,794	6,070,358	2,552,505	19,612,510	3,246,066	378,976	**34,999,209**
Acidification Potential (moles of H+ eq / kg)	2,086,089	4,424,765	1,576,470	10,864,614	2,124,948	253,765	**21,330,651**
HH Respiratory Effects Potential (kg PM2.5 eq / kg)	1,559,829	3,126,488	1,337,963	9,754,424	1,647,410	189,520	**17,615,635**
Eutrophication Potential (kg N eq / kg)	56,887	281,718	71,525	719,988	77,912	6,392	**1,214,422**
Ozone Depletion Potential (kg CFC-11 eq / kg)	1,556,390	3,107,597	1,335,781	9,737,326	1,644,033	189,075	**17,570,202**
Smog Potential (kg NOx eq / kg)	1,564,512	3,123,700	1,337,862	9,761,178	1,652,003	190,054	**17,629,310**

5.2 SUMMARY MEASURES BY LIFE ASSEMBLY GROUP DESCRIPTION

This table describes the summary measures by assembly group. As a default this analysis includes six assembly groups, which are: extra basic materials, floors, roofs, columns & beams, walls, and foundations.

It can be seen in the primary energy consumption row that the majority of the energy consumption occurs in the 'roofs' category. This is understandable because of the nature of the materials used in the roof systems. The steel roof decking, membrane, and built up tar & gravel roof, insulation, double layer gypsum board, and engineered wood truss joist systems makes it a material group with many high embodied energy materials. Another major contributor to the 'roofs' category is the ~50,000ft^2 concrete roof added above the parkade, which was situated below each apartment block.

Similar to the life cycle stage summary measures table, it is again difficult to determine which summary measures are dominating because of the difference in units among these measures. For a better idea of how the summary measures vary with respect to the use of different construction materials, please refer to the sensitivity analysis shown in section 5.4.

5.3 SUMMARY MEASURE CATEGORIES

5.3.1 Primary Energy

Primary energy is reported in mega-joules (MJ). Primary energy includes all energy, direct and indirect, used to transform or transport raw materials into products and buildings, including inherent energy contained in raw or feedstock materials that are also used as common energy sources. (For example, natural gas used as a raw material in the production of various plastic (polymer) resins.) In addition, the Impact Estimator captures the indirect energy use associated with processing, transporting, converting and delivering fuel and energy. (Athena IE 4.0.51 Definition)

5.3.2 Acidification Potential

Acidification potential is a more regional rather than global impact effecting human health when high concentrations of NO_x and SO_2 are attained. The AP of an air or water emission is calculated on the basis of its H^+ equivalence effect on a mass basis. (Athena IE 4.0.51 Definition)

Due to the fact that our analysis did not take into account regional factors, this result carries a high level of uncertainty.

5.3.3 Aquatic Eutrophication Potential

Eutrophication is the fertilization of surface waters by nutrients that were previously scarce. When a previously scarce or limiting nutrient is added to a water body it leads to the proliferation of aquatic photosynthetic plant life. This may lead to a chain of further consequences ranging from foul odours to the death of fish. The calculated result is expressed on an equivalent mass of nitrogen (N) basis. (Athena IE 4.0.51 Definition)

5.3.4 Global Warming Potential

Global warming potential is a reference measure. The methodology and science behind the GWP calculation can be considered one of the most accepted life cycle impact assessment (LCIA) categories. GWP will be expressed on an equivalency basis relative to CO_2 – in kg or tonnes CO_2 equivalent. Carbon dioxide is the common reference standard for global warming or greenhouse gas effects. All other greenhouse gases are referred to as having a "CO_2 equivalence effect" which is simply a multiple of the greenhouse potential (heat trapping capability) of carbon dioxide. This effect has a time horizon due to the atmospheric reactivity or stability of the various contributing gases over time. (Athena IE 4.0.51 Definition)

5.3.5 Human Health Criteria Air-Mobile

Particulate matter of various sizes (PM_{10} and $PM_{2.5}$) have a considerable impact on human health. The EPA has identified "particulates" (from diesel fuel combustion) as the number one cause of human health deterioration due to its impact on the human respiratory system – asthma, bronchitis, acute pulmonary disease, etc. It should be mentioned that particulates are an important environmental output of plywood product production and need to be traced and addressed. The Institute used TRACI’s "Human Health Particulates from Mobile Sources" characterization factor, on an equivalent $PM_{2.5}$ basis, in our final set of impact indicators. (Athena IE 4.0.51 Definition)

5.3.6 Ozone Depletion

Stratospheric ozone depletion potential accounts for impacts related to the reduction of the protective ozone layer within the stratosphere caused by emissions of ozone depleting substances (CFCs, HFCs, and halons). The ozone depletion potential of each of the contributing substances is characterized relative to CFC-11, with the final impact indicator indicating mass (e.g., kg) of equivalent CFC-11. (Athena IE 4.0.51 Definition)

5.3.7 Raw Resource Use

The Weighted Resource Use values reported by the Impact Estimator are the sum of the weighted resource requirements for all products used in each of the designs. They can be thought of as "ecologically weighted kilograms", where the weights reflect expert opinion about the relative ecological carrying capacity effects of extracting resources. Excluded from this measure are energy feedstocks used as raw materials. Except for coal, no scoring survey has been conducted on the effects of extracting fossil fuels, and hence, they have been assigned a score of one to only account for their mass (Athena IE 4.0.51 Definition). The raw material weighting is as follows:

Weighted Resource Use is the same as normal resource converted to mass quantities except:

1. LIMESTONE * 1.5
2. IRON ORE * 2.25
3. COAL * 2.25
4. WOODFIBER * 2.5

5.3.8 Smog

Under certain climatic conditions, air emissions from industry and transportation can be trapped at ground level where, in the presence of sunlight, they produce photochemical smog, a symptom of photochemical ozone creation potential (POCP). 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 ethylene basis. (Athena IE 4.0.51 Definition)

5.4 SENSITIVITY ANALYSIS

As seen in the table below, the highlighted materials were chosen as the subjects of this sensitivity analysis. The sensitivity analysis was conducted by adding an additional 10% of the original material quantity, to the original material quantity, for each of the highlighted materials. The purpose of the sensitivity analysis was to observe how the Thunderbird residence's summary measures are affected by such a material increase.

Table 5. Thunderbird Residences, Sensitivity Analysis

Material	Quantity	Unit	Amount to add to XBM
#15 Organic Felt		m2	
1/2" Regular Gypsum Board	56,827	m2	5,166
3 mil Polyethylene		m2	
5/8" Regular Gypsum Board		m2	
6 mil Polyethylene		m2	
Aluminium		Tonnes	
Ballast (aggregate stone)		Kg	
Batt. Fiberglass	174,460	m2 (25mm)	15,860
Blown Cellulose		m2 (25mm)	
Cold Rolled Sheet		Tonnes	
Concrete 30 MPa (flyash av)	31,996	m3	2,909
Concrete Brick		m2	
EPDM membrane		Kg	
Expanded Polystyrene		m2 (25mm)	
Galvanized Sheet		Tonnes	
Hollow Structural Steel		Tonnes	
Joint Compound		Tonnes	
Laminated Veneer Lumber		m3	
Large Dimension Softwood Lumber,		m3	
Mortar		m3	
Nails		Tonnes	
Paper Tape		Tonnes	
Rebar, Rod, Light Sections		Tonnes	
Roofing Asphalt		Kg	
Screws Nuts & Bolts		Tonnes	
Small Dimension Softwood Lumber,		m3	
Small Dimension Softwood Lumber,	2,124	m3	193
Softwood Plywood		m2 (9mm)	
Solvent Based Alkyd Paint		L	
Standard Glazing	10,564	m2	960
Stucco over metal mesh		m2	
Type III Glass Felt		m2	
Water Based Latex Paint		L	
Welded Wire Mesh / Ladder Wire		Tonnes	

Table 6. Sensitivity Analysis for Concrete 30 MPa (flyash av)

Sensitivity Analysis With 10% More Concrete 30 MPa (flyash av)					
Classification	Manufacturing and Construction				
	Current Building		Modified Building		Percent difference (%)
	Overall	Per Sq. Ft	Overall	Per Sq. Ft	
Primary Energy Consumption MJ	303,142,862.1	495.4	308,657,751.3	504.5	1.8
Weighted Resource Use kg	111,779,199.9	182.7	119,967,277.3	196.1	7.3
Global Warming Potential (kg CO2 eq / kg)	17,375,230.7	28.4	18,199,546.8	29.7	4.7
Acidification Potential (moles of H+ eq / kg)	3,733,148.3	6.1	4,014,219.2	6.6	7.5
HH Respiratory Effects Potential (kg PM2.5 eq / kg)	45,404.0	0.1	47,339.5	0.1	4.3
Eutrophication Potential (kg N eq / kg)	1,586.6	0.0	1,587.0	0.0	0.0
Ozone Depletion Potential (kg CFC-11 eq / kg)	0.1	0.0	0.1	0.0	1.8
Smog Potential (kg NOx eq / kg)	58,521.1	0.1	62,797.7	0.1	7.3

Table 7. Sensitivity Analysis for Small Dimension Softwood Lumber, kiln-dried

Sensitivity Analysis With 10% More Small Dimension Softwood Lumber, kiln-dried					
Classification	Manufacturing and Construction				
	Current Building		Modified Building		Percent difference (%)
	Overall	Per Sq. Ft	Overall	Per Sq. Ft	
Primary Energy Consumption MJ	303,142,862.1	495.4	303,502,689.6	496.0	0.1
Weighted Resource Use kg	111,779,199.9	182.7	112,094,681.8	183.2	0.3
Global Warming Potential (kg CO2 eq / kg)	17,375,230.7	28.4	17,382,847.0	28.4	0.0
Acidification Potential (moles of H+ eq / kg)	3,733,148.3	6.1	3,735,418.5	6.1	0.1
HH Respiratory Effects Potential (kg PM2.5 eq / kg)	45,404.0	0.1	45,422.8	0.1	0.0
Eutrophication Potential (kg N eq / kg)	1,586.6	0.0	1,586.6	0.0	0.0
Ozone Depletion Potential (kg CFC-11 eq / kg)	0.1	0.0	0.1	0.0	2.5
Smog Potential (kg NOx eq / kg)	58,521.1	0.1	58,528.5	0.1	0.0

Table 8. Sensitivity Analysis for Fiberglass Batt. Insulation

Sensitivity Analysis With 10% More Fiberglass Batt. Insulation					
Classification	Manufacturing and Construction				
	Current Building		Modified Building		Percent difference (%)
	Overall	Per Sq. Ft	Overall	Per Sq. Ft	
Primary Energy Consumption MJ	303,142,862.1	495.4	303,428,341.5	495.9	0.1
Weighted Resource Use kg	111,779,199.9	182.7	111,811,140.7	182.7	0.0
Global Warming Potential (kg CO2 eq / kg)	17,375,230.7	28.4	17,393,652.5	28.4	0.1
Acidification Potential (moles of H+ eq / kg)	3,733,148.3	6.1	3,740,008.5	6.1	0.2
HH Respiratory Effects Potential (kg PM2.5 eq / kg)	45,404.0	0.1	45,558.6	0.1	0.3
Eutrophication Potential (kg N eq / kg)	1,586.6	0.0	1,586.6	0.0	0.0
Ozone Depletion Potential (kg CFC-11 eq / kg)	0.1	0.0	0.1	0.0	0.0
Smog Potential (kg NOx eq / kg)	58,521.1	0.1	58,546.9	0.1	0.0

Table 9. Sensitivity Analysis for Standard Glazing

Sensitivity Analysis With 10% More Standard Glazing					
Classification	Manufacturing and Construction				
	Current Building		Modified Building		Percent difference (%)
	Overall	Per Sq. Ft	Overall	Per Sq. Ft	
Primary Energy Consumption MJ	303,142,862.1	495.4	303,221,903.9	495.6	0.0
Weighted Resource Use kg	111,779,199.9	182.7	111,811,752.7	182.7	0.0
Global Warming Potential (kg CO2 eq / kg)	17,375,230.7	28.4	17,399,977.0	28.4	0.1
Acidification Potential (moles of H+ eq / kg)	3,733,148.3	6.1	3,746,408.9	6.1	0.4
HH Respiratory Effects Potential (kg PM2.5 eq / kg)	45,404.0	0.1	45,778.4	0.1	0.8
Eutrophication Potential (kg N eq / kg)	1,586.6	0.0	1,586.6	0.0	0.0
Ozone Depletion Potential (kg CFC-11 eq / kg)	0.1	0.0	0.1	0.0	0.0
Smog Potential (kg NOx eq / kg)	58,521.1	0.1	58,670.3	0.1	0.3

Table 10. Sensitivity Analysis for 1/2" Regular Gypsum Board

Sensitivity Analysis With 10% More 1/2" Regular Gypsum Board					
Classification	Manufacturing and Construction				
	Current Building		Modified Building		Percent difference (%)
	Overall	Per Sq. Ft	Overall	Per Sq. Ft	
Primary Energy Consumption MJ	303,142,862.1	495.4	303,393,257.9	495.9	0.1
Weighted Resource Use kg	111,779,199.9	182.7	111,835,783.7	182.8	0.1
Global Warming Potential (kg CO2 eq / kg)	17,375,230.7	28.4	17,387,909.1	28.4	0.1
Acidification Potential (moles of H+ eq / kg)	3,733,148.3	6.1	3,737,777.1	6.1	0.1
HH Respiratory Effects Potential (kg PM2.5 eq / kg)	45,404.0	0.1	45,445.1	0.1	0.1
Eutrophication Potential (kg N eq / kg)	1,586.6	0.0	1,586.6	0.0	0.0
Ozone Depletion Potential (kg CFC-11 eq / kg)	0.1	0.0	0.1	0.0	0.0
Smog Potential (kg NOx eq / kg)	58,521.1	0.1	58,531.4	0.1	0.0

5.4.1 Results of the Sensitivity Analysis

As observed in the above tables, the two materials that had the most noticeable affects in the analysis were concrete, and softwood lumber. There is a direct correlation between this result and these materials being the most used in the construction of the residences. A more meaningful way to conduct this analysis would be to model the same building with two different primary materials in order to observe the summary measure differences. This, however, would be much more time consuming than the above analysis, which is appropriate for a quick check of which materials dominate the summary measure effects.

5.4.2 Role of the Sensitivity Analysis in The Construction Industry

If all buildings construction choices were made based on environmental impacts, just as they are made currently based on cost, a significant environmental benefit would be experienced. It is most logical to perform a sensitivity analysis either in the principal stages of construction planning, or when considering a major renovation. With knowledge of regional data for a subject construction project, a sensitivity analysis could translate into significant environmental savings for an ecosystem. An example of this would be an area close to a mine site. In this area there may be more considerations given to acidification, due to the higher local concentrations of H_2SO_4 created from the acidic mine drainage. A sensitivity analysis could be conducted for this area to determine which materials are the best choices to minimize acidification, thus lessening the human impact on the local ecosystem.

6.0 BUILDING PERFORMANCE

As building heating is one of the greatest demands on fossil fuels in Canada, it is important to understand what can be done to reduce a building's fossil fuel consumption. The majority of buildings in North America have been built solely with cost in mind, and in this way they are built with sufficient insulation systems to maintain a comfortable temperature only when supplemented by high energy input (in the colder seasons). Energy input is necessary to maintain comfortable temperature levels, however, this demand of energy could be significantly reduced with the employment of better insulating building materials. In this building performance analysis, the Vancouver seasonal temperature data has been applied with the insulating characteristics of the Thunderbird residences, in order to determine the amount of heat loss through the building's walls, windows and roofs. The heat loss equation used is as follows:

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

Where,

R = Calculated R-Value in ft^2 ºF h/BTU (Imperial units)

A = Assembly of interest ft^2

ΔT = Inside Temperature – Outside Temperature in ºF

Following the calculations for our current building, another "improved" building model was created to compare the energy payback periods of upgrading envelope materials. The improved building model is the current building model upgraded to meet the insulation requirements of UBC's Residential Environmental Assessment Program (REAP). The REAP insulation requirements are as follows:

- 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

In order to increase the energy efficiency of the residences, and achieve REAP's requirements, the thicknesses of fiberglass batt type insulation were increased in the walls and roof, and low E tin argon glazing was used for the windows. The three following inputs were added into the 'Extra Basic Materials' section of the current IE model, to achieve of the improved model:

Walls: F. Batt. 2" insulation x 148,302 SF / 1.05_{waste} = **281,773 SF/1" Thickness**

Roof: F. Batt. 5" insulation x 86,155SF / 1.05_{waste} = **409,235 SF/1" Thickness**

Windows: low E tin argon glazing (replaced former glazing)

Table 11. Thunderbird Residences Embodied Energy Comparison

Embodied Energy Comparison			
Classification	Manufacturing and Construction		
	Current Building	Improved Building	Percent difference (%)
Electricity kWh	12,842,736	12,862,478	0.2
Hydro MJ	41,809,468	41,815,271	0.0
Coal MJ	22,386,774	22,583,873	0.9
Diesel MJ	41,475,117	41,586,615	0.3
Feedstock MJ	106,427,449	106,427,449	0.0
Gasoline MJ	98,379	98,379	0.0
Heavy Fuel Oil MJ	9,369,176	9,379,650	0.1
LPG MJ	83,527	84,042	0.6
Natural Gas MJ	112,445,691	113,282,723	0.7
Nuclear MJ	5,240,086	5,241,741	0.0
Wood MJ	5,616,353	5,616,353	0.0
Total MJ	357,794,757	358,978,575	0.3

As identified by the above table, the embodied energy is minimally affected by the additions of the insulating materials, with 0.3% increase for the improved building. The graph below illustrates the energy improvement payback period. The energy payback period is the length of time it takes for the energy savings of the improved building to equal the amount of embodied energy in the materials used to improve the building's energy efficiency.

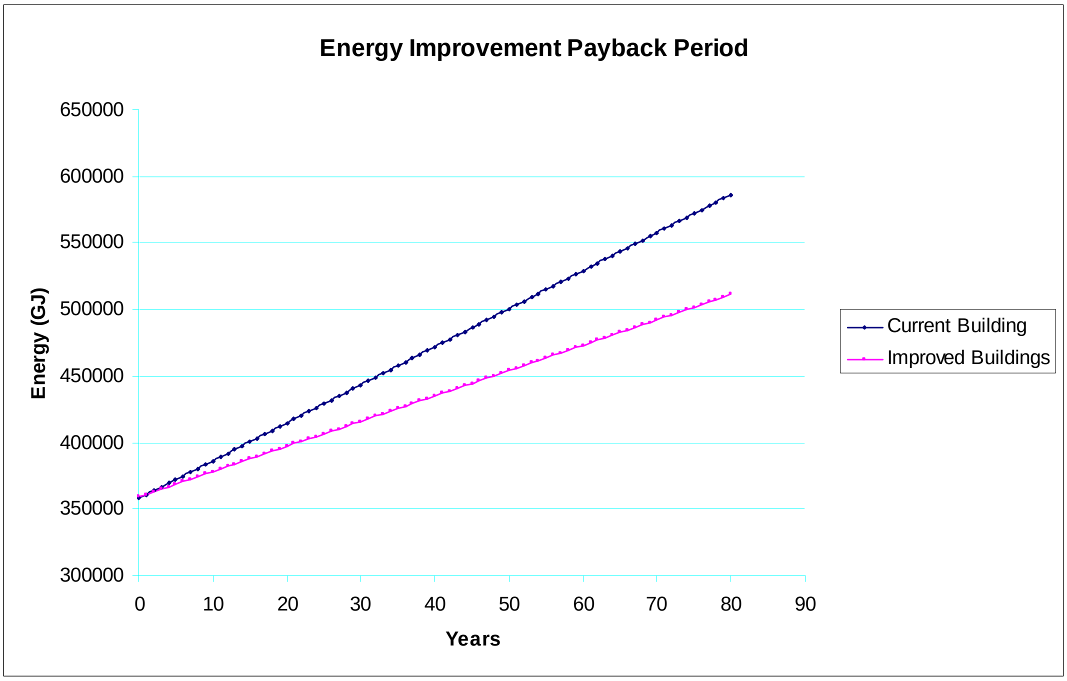


Figure 6. Energy Improvement Payback period

As illustrated by the above graph, the energy payback period for the residences was found to be 1 year, and every year thereafter would provide an energy savings. The two following tables display the energy loss through the current and improved buildings when applied to monthly Vancouver temperatures.

Table 12. Monthly Energy Loss, Current Building

Current Building							
Temperature					Energy Loss		
Month	Days Per Month	Historical Avg. (deg C)	Historical Avg. (deg F)	Temp.Diff. (deg F)	(BTU used per month)	(kWh used per month)	(J used per month)
Jan	31	3.6	38.48	29.52	377,473,736.16	110,626.64	398,255,892,427.81
Feb	28	4.9	40.82	27.18	313,917,969.41	92,000.28	331,201,005,740.51
Mar	31	6.6	43.88	24.12	308,423,662.47	90,390.06	325,404,204,788.58
Apr	30	9.1	48.38	19.62	242,788,968.77	71,154.43	256,155,933,957.30
May	31	12.3	54.14	13.86	177,228,522.46	51,940.56	186,985,998,274.03
Jun	30	14.7	58.46	9.54	118,053,351.79	34,598.02	124,552,885,318.69
Jul	31	16.9	62.42	5.58	71,351,742.81	20,911.13	75,280,077,227.21
Aug	31	17.1	62.78	5.22	66,748,404.56	19,562.03	70,423,298,051.26
Sep	30	14.5	58.1	9.90	122,508,195.25	35,903.61	129,252,994,198.64
Oct	31	10.3	50.54	17.46	223,261,904.92	65,431.61	235,553,790,033.52
Nov	30	6.1	42.98	25.02	309,611,620.73	90,738.21	326,657,567,156.56
Dec	31	3.8	38.84	29.16	372,870,397.91	109,277.53	393,399,113,251.86
Annual	30	10.0	49.99	18.02	2,704,238,477.25	792,534.10	2,853,122,760,425.97

Table 13. Monthly Energy Loss, Improved Building

Improved Building							
Temperature					Energy Loss		
Month	Days Per Month	Historical Avg. (deg C)	Historical Avg. (deg F)	Temp.Diff. (deg F)	(BTU used per month)	(kWh used per month)	(J used per month)
Jan	31	3.6	38.48	29.52	251,750,626.95	73,780.83	265,610,984,296.62
Feb	28	4.9	40.82	27.18	209,363,031.23	61,358.25	220,889,701,338.73
Mar	31	6.6	43.88	24.12	205,698,683.00	60,284.34	217,023,609,120.41
Apr	30	9.1	48.38	19.62	161,924,577.13	47,455.41	170,839,480,458.29
May	31	12.3	54.14	13.86	118,199,989.48	34,641.00	124,707,596,285.61
Jun	30	14.7	58.46	9.54	78,733,968.70	23,074.65	83,068,738,204.49
Jul	31	16.9	62.42	5.58	47,587,008.75	13,946.38	50,206,954,348.75
Aug	31	17.1	62.78	5.22	44,516,879.16	13,046.61	46,967,796,003.67
Sep	30	14.5	58.1	9.90	81,705,061.86	23,945.39	86,203,407,570.70
Oct	31	10.3	50.54	17.46	148,901,285.45	43,638.66	157,099,179,736.42
Nov	30	6.1	42.98	25.02	206,490,974.51	60,516.53	217,859,520,951.40
Dec	31	3.8	38.84	29.16	248,680,497.36	72,881.06	262,371,825,951.54
Annual	30	10.0	49.99	18.02	1,803,552,583.58	528,569.11	1,902,848,794,266.64

7.0 CONCLUSION

This cradle-to-gate LCA of the Thunderbird residences demonstrated a primary energy consumption of 3.0×10^8 MJ, or 496 MJ/ft^2. It was found that the manufacturing life cycle stage accounted for more than 90% of the primary energy consumption. The IE summary measures indicated levels of energy consumption, acidification potential, global warming potential, Human Health Criteria Air-Mobile, ozone depletion potential, smog potential, eutrophication potential and weighted resource use. These summary measures provided the basis for further analysis, which could be comparatively analyzed to other buildings, or an analysis addressing regional concerns.

Through the use of a sensitivity analysis it was determined that concrete and wood had the greatest influence on the summary measures of the five different materials chosen. In the case modeled the sensitivity analysis results were related to the amount of subject material contained within the building.

The final consideration in this analysis was energy consumption. It was observed that with a 0.3% increase in total embodied energy in building insulation systems, the energy performance can be significantly improved with an energy payback period of one year, and subsequent energy savings thereafter.

The results of this analysis for the Thunderbird residences can now be applied in comparison with other buildings, on a square foot residence basis, in order to determine the effects on the environment of using different construction materials and assembly types.

ANNEX “A” – IMPACT ESTIMATOR INPUT TABLES

Assembly Group	Assembly Type	Input Fields	Ideal Inputs	IE Input	Total Site (One Block x 5)
1a) Add Foundation					
	Concrete Footing Foundation (Spread Footings)				
		Length (ft)	Varies	73'	**365**
		Width (ft)	Varies	73'	**73**
		Thickness (in)	Varies	19.7"	**19.7**
		Concrete (Psi)	3500	4000	
		Rebar Size	#6	#6	
		Concrete flyash %	-	average	
1b) Add Foundation					
	Concrete Footing Foundation (Perimeter Footing)				
		Length (ft)	1142'	1142'	**5710**
		Width (ft)	1.5'	1.5'	**1.5**
		Thickness (in)	10"	10"	**10**
		Concrete (Psi)	3500	4000	
		Rebar Size	#5	#5	
		Concrete flyash %	average	average	
1c) Add Foundation					
	Concrete Slab on Grade				
		Length (ft)	392'	392'	**1960**
		Width (ft)	172'	172'	**172**
	`	Thickness (in)	4"	4"	**4**
		Concrete (Psi)	3500	4000	
		Concrete flyash %	average	average	
1d) Add Foundation					
	Extras - Stairs				
		Length (ft)	ideal is in volume	48	**240**
		Width (ft)	876CF	20	**20**
		Thickness (in)	6"	8"	**8**
		Concrete (Psi)	3500	4000	
		Concrete flyash %	average	average	
1e) Add Foundation					
	Extras - Balconies				
		Length (ft)		94.4	**472**
		Width (ft)		20	**20**
		Thickness (in)	6"	8	**8**
		Concrete (Psi)	3500	4000	
		Concrete flyash %	average	average	
2a)Add Beams and Columns					
	Concrete Beam and Column (R Conc)				
	Parkade	Number of beams	8	8	**40**
		Number of columns	139	139	**695**
		Floor to floor height (ft)	14'	14'	
		Bay sizes (ft)	21'	21	
		Supported span	26'	26	
		Live load (psf)	Mixed Ave 75	75	
2b)Add Beams and Columns					
	LVL Beam and Column (mixed)				

	First Floor (main)	LVL beams	79	79	**395**
		BU Lumber columns	143	143	**715**
		Steel columns	18	18	**90**
		PSL columns	15	15	**75**
		Floor to floor height (ft)	9.2'		
		Bay sizes (ft)	Various	20'	
		Supported span	Various	20'	
		Live load (psf)	40	45	
2c)Add Beams and Columns					
	LVL Beam and Column (mixed)				
	Second Floor	LVL beams	79	79	**395**
		BU Lumber columns	143	143	**715**
		Steel columns	18	18	**90**
		PSL columns	15	15	**75**
		Floor to floor height (ft)	9.2'		
		Bay sizes (ft)	Various	20'	
		Supported span	Various	20'	
		Live load (psf)	40	45	
2d)Add Beams and Columns					
	LVL Beam and Column (mixed)				
	Third Floor	PSL beams	59	59	**295**
		BU Lumber columns	96	96	**480**
		Floor to floor height (ft)	9.2'		
		Bay sizes (ft)	Various	20'	
		Supported span	Various	20'	
		Live load (psf)	40	45	
2e)Add Beams and Columns					
	LVL Beam and Column (mixed)				
	Fourth Floor	PSL beams	59	59	**295**
		BU Lumber columns	96	96	**480**
		Floor to roof height (ft)	10'		
		Bay sizes (ft)	Various	20'	
		Supported span	Various	20'	
		Live load (psf)	40	45	
3a) Add Floors					
	Structural First Floor				
		Area	17,231SF		
		Width (ft)		408	**2040**
		Span (ft)		42	**42**
		Concrete (Psi)	3500	4000	
		Concrete flyash %	average	average	
		Live load (psf)	40	45	

		Floor type	Suspended Floor Slab (poured + 2” topping above rigid insulation)	Suspended Floor Slab	
3b) Add Floors					
	Structural second Floor				
		Area	17,231SF		
		Width (ft)		408'	**2040**
		Span (ft)		42'	**42**
		Live load (psf)	40	45	
		Floor type	1.5" concrete topping5/8" plywood12" wood truss-joist5/8" gypsum wall board	Light frame wood truss floor	
3c) Add Floors					
	Structural third Floor				
		Area	10,812 SF		
		Width (ft)		318	**1592**
		Span (ft)		34'	**34**
		Live load (psf)	40	45	
		Floor type	1.5" concrete topping 5/8" plywood 12" wood truss-joist 5/8" gypsum wall board	Light frame wood truss floor	
3d) Add Floors					
	Structural fourth Floor				
			9,660 SF		
		Width (ft)		284	**1420**
		Span (ft)		34'	**34**
		Live load (psf)	40	45	
		Floor type	1.5" concrete topping 5/8" plywood 12" wood truss-joist 5/8" gypsum wall board	Light frame wood truss floor	**1240 x 6 x .5**
4a) Add Roof					
	2-Storey Roof				
		Area	5,411 SF		
		Width (ft)		193	**965**
		Span (ft)		28	**28**
		Live load (psf)	107	100	

		Roof type	metal Deck membrane cover 1/2" plywood wood joist (2x4) and purlin (2x8) 2 x 5/8" gypsum wall		
4b) Add Roof					
	4-Storey Roof				
		Area	9660 SF		
		Width (ft)		345	**1725**
		Span (ft)		28	**28**
		Live load (psf)	107	100	
		Roof type	Built-Up T&G System1/2" plywood12" wood truss-joist2 x 5/8" gypsum wall board		
4c) Add Roof					
	Parkade Roof				
		Area 67,424-17,231SF	50,193SF		
		Width (ft)		334	**1670**
		Span (ft)		150	**150**
		Live load (psf)	107	100	
		Materials .			
		Roof type	Concrete Suspended Slab		
5a) Add Walls					
	parkade				
		Wall Type	Exterior	Exterior	
		Length (ft)	1733	1733	**8665**
		Height (ft)	14	14	**14**
		Total opening area (ft2)	n/a	n/a	
		Number of window units	n/a	n/a	
		Sheathing	n/a	n/a	
		wall thickness	approx 6"	8"	
		MaterialType	Cast in place	Cast in place	
5b) Add Walls					
	A4 Stucco				
		Wall Type	Exterior	Exterior	

		Length (ft)	72	72	**360**
		Height (ft)	21	21	**21**
		Total opening area (ft2)	n/a	347.6	**1738**
		Number of window units	n/a	19.2	**96**
		Number of Doors	5	5	**25**
		Sheathing	plywood	plywood	**n/a**
		Stud thickness	2 x 4	2 x 4	**n/a**
		Stud Spacing	n/a	16 o/c	**n/a**
		Stud Type	kiln dried	kiln dried	**n/a**
5b) Add Walls (2)					
	A4 Stucco (2)				
		Wall Type	Exterior	Exterior	
		Length (ft)	30	30	**150**
		Height (ft)	21	21	**21**
		Total opening area (ft2)	n/a	37.8	**189**
		Number of window units	n/a	2.2	**11**
		Number of doors	0	0	**0**
		Sheathing	plywood	plywood	**n/a**
		Stud thickness	2 x 4	2 x 4	**n/a**
		Stud Spacing	n/a	16 o/c	**n/a**
		Stud Type	kiln dried	kiln dried	**n/a**
5c) Add Walls					
	A4 Brick				
		Wall Type	Exterior	Exterior	
		Length (ft)	85	85	**425**
		Height (ft)	22	22	**22**
		Total opening area (ft2)	337	337	**1685**
		Number of window units	18.7	18.7	**93.5**
		Number of doors	5	5	**25**
		Sheathing	plywood	plywood	**n/a**
		Stud thickness	2 x 4	2 x 4	**n/a**
		Stud Spacing	n/a	16 o/c	**n/a**
		Stud Type	kiln dried	kiln dried	**n/a**
5c) Add Walls (2)					
	A4 Brick (2)				
		Wall Type	Exterior	Exterior	
		Length (ft)	85	85	**425**
		Height (ft)	22	22	**22**
		Total opening area (ft2)	337	337	**1685**
		Number of window units	18.7	18.7	**93.5**
		Number of doors	5	5	**25**
		Sheathing	plywood	plywood	**n/a**
		Stud thickness	2 x 4	2 x 4	**n/a**
		Stud Spacing	n/a	16 o/c	**n/a**
		Stud Type	kiln dried	kiln dried	**n/a**
5c) Add Walls (3)					
	A4 Brick (3)				
		Wall Type	Exterior	Exterior	
		Length (ft)	85	85	**425**
		Height (ft)	22	22	**22**
		Total opening area (ft2)	337	337	**1685**

		Number of window units	18.7	18.7	**93.5**
		Number of doors	5	5	**25**
		Sheathing	plywood	plywood	**n/a**
		Stud thickness	2 x 4	2 x 4	**n/a**
		Stud Spacing	n/a	16 o/c	**n/a**
		Stud Type	kiln dried	kiln dried	**n/a**
5d) Add Walls					
	A1 Brick 1st and 2nd Floor				
		Wall Type	Exterior	Exterior	
		Length (ft)	96	96	**480**
		Height (ft)	18.5	18.5	**18.5**
		Total opening area (ft2)	320	320	**1600**
		Number of window units	17.8	17.8	**89**
		Number of doors	2.5	2.5	**12.5**
		Sheathing	plywood	plywood	**n/a**
		Stud thickness	2 x 4	2 x 4	**n/a**
		Stud Spacing	n/a	16 o/c	**n/a**
		Stud Type	kiln dried	kiln dried	**n/a**
5d) Add Walls (2)					
	A1 Brick 1st and 2nd Floor (2)				
		Wall Type	Exterior	Exterior	
		Length (ft)	96	96	**480**
		Height (ft)	18.5	18.5	**18.5**
		Total opening area (ft2)	320	320	**1600**
		Number of window units	17.8	17.8	**89**
		Number of doors	2.5	2.5	**12.5**
		Sheathing	plywood	plywood	**n/a**
		Stud thickness	2 x 4	2 x 4	**n/a**
		Stud Spacing	n/a	16 o/c	**n/a**
		Stud Type	kiln dried	kiln dried	**n/a**
5d) Add Walls (3)					
	A1 Brick 1st and 2nd Floor (3)				
		Wall Type	Exterior	Exterior	
		Length (ft)	96	96	**480**
		Height (ft)	18.5	18.5	**18.5**
		Total opening area (ft2)	320	320	**1600**
		Number of window units	17.8	17.8	**89**
		Number of doors	2.5	2.5	**12.5**
		Sheathing	plywood	plywood	**n/a**
		Stud thickness	2 x 4	2 x 4	**n/a**
		Stud Spacing	n/a	16 o/c	**n/a**
		Stud Type	kiln dried	kiln dried	**n/a**
5d) Add Walls (4)					
	A1 Brick 1st and 2nd Floor (4)				
		Wall Type	Exterior	Exterior	
		Length (ft)	96	96	**480**
		Height (ft)	18.5	18.5	**18.5**
		Total opening area (ft2)	320	320	**1600**
		Number of window	17.8	17.8	**89**

		units			
		Number of doors	2.5	2.5	**12.5**
		Sheathing	plywood	plywood	**n/a**
		Stud thickness	2 x 4	2 x 4	**n/a**
		Stud Spacing	n/a	16 o/c	**n/a**
		Stud Type	kiln dried	kiln dried	**n/a**
5d) Add Walls (5)					
	A1 Brick 1st and 2nd Floor (5)				
		Wall Type	Exterior	Exterior	
		Length (ft)	96	96	**480**
		Height (ft)	18.5	18.5	**18.5**
		Total opening area (ft2)	320	320	**1600**
		Number of window units	17.8	17.8	**89**
		Number of doors	2.5	2.5	**12.5**
		Sheathing	plywood	plywood	**n/a**
		Stud thickness	2 x 4	2 x 4	**n/a**
		Stud Spacing	n/a	16 o/c	**n/a**
		Stud Type	kiln dried	kiln dried	**n/a**
5d) Add Walls (6)					
	A1 Brick 1st and 2nd Floor (6)				
		Wall Type	Exterior	Exterior	
		Length (ft)	96	96	**480**
		Height (ft)	18.5	18.5	**18.5**
		Total opening area (ft2)	320	320	**1600**
		Number of window units	17.8	17.8	**89**
		Number of doors	2.5	2.5	**12.5**
		Sheathing	plywood	plywood	**n/a**
		Stud thickness	2 x 4	2 x 4	**n/a**
		Stud Spacing	n/a	16 o/c	**n/a**
		Stud Type	kiln dried	kiln dried	**n/a**
5d) Add Walls (7)					
	A1 Brick 1st and 2nd Floor (7)				
		Wall Type	Exterior	Exterior	
		Length (ft)	96	96	**480**
		Height (ft)	18.5	18.5	**18.5**
		Total opening area (ft2)	320	320	**1600**
		Number of window units	17.8	17.8	**89**
		Number of doors	2.5	2.5	**12.5**
		Sheathing	plywood	plywood	**n/a**
		Stud thickness	2 x 4	2 x 4	**n/a**
		Stud Spacing	n/a	16 o/c	**n/a**
		Stud Type	kiln dried	kiln dried	**n/a**
5d) Add Walls (8)					
	A1 Brick 1st and 2nd Floor (8)				
		Wall Type	Exterior	Exterior	
		Length (ft)	96	96	**480**
		Height (ft)	18.5	18.5	**18.5**
		Total opening area	320	320	**1600**

		(ft2)			
		Number of window units	17.8	17.8	**89**
		Number of doors	2.5	2.5	**12.5**
		Sheathing	plywood	plywood	**n/a**
		Stud thickness	2 x 4	2 x 4	**n/a**
		Stud Spacing	n/a	16 o/c	**n/a**
		Stud Type	kiln dried	kiln dried	**n/a**
5e) Add Walls					
	A1 Brick 3rd and 4th Floor				
		Wall Type	Exterior	Exterior	
		Length (ft)	99	99	**495**
		Height (ft)	18.5	18.5	**18.5**
		Total opening area (ft2)	311	311	**1555**
		Number of window units	18	18	**90**
		Number of doors	9	9	**45**
		Sheathing	plywood	plywood	**n/a**
		Stud thickness	2 x 4	2 x 4	**n/a**
		Stud Spacing	n/a	16 o/c	**n/a**
		Stud Type	kiln dried	kiln dried	**n/a**
5e) Add Walls (2)					
	A1 Brick 3rd and 4th Floor (2)				
		Wall Type	Exterior	Exterior	
		Length (ft)	99	99	**495**
		Height (ft)	18.5	18.5	**18.5**
		Total opening area (ft2)	311	311	**1555**
		Number of window units	18	18	**90**
		Number of doors	9	9	**45**
		Sheathing	plywood	plywood	**n/a**
		Stud thickness	2 x 4	2 x 4	**n/a**
		Stud Spacing	n/a	16 o/c	**n/a**
		Stud Type	kiln dried	kiln dried	**n/a**
5e) Add Walls (3)					
	A1 Brick 3rd and 4th Floor (3)				
		Wall Type	Exterior	Exterior	
		Length (ft)	99	99	**495**
		Height (ft)	18.5	18.5	**18.5**
		Total opening area (ft2)	311	311	**1555**
		Number of window units	18	18	**90**
		Number of doors	9	9	**45**
		Sheathing	plywood	plywood	**n/a**
		Stud thickness	2 x 4	2 x 4	**n/a**
		Stud Spacing	n/a	16 o/c	**n/a**
		Stud Type	kiln dried	kiln dried	**n/a**
5e) Add Walls (4)					
	A1 Brick 3rd and 4th Floor (4)				
		Wall Type	Exterior	Exterior	
		Length (ft)	99	99	**495**
		Height (ft)	18.5	18.5	**18.5**

		Total opening area (ft2)	311	311	**1555**
		Number of window units	18	18	**90**
		Number of doors	9	9	**45**
		Sheathing	plywood	plywood	**n/a**
		Stud thickness	2 x 4	2 x 4	**n/a**
		Stud Spacing	n/a	16 o/c	**n/a**
		Stud Type	kiln dried	kiln dried	**n/a**
5f) Add Walls					
	A1 Stucco				
		Wall Type	Exterior	Exterior	
		Length (ft)	104	104	**520**
		Height (ft)	18.5	18.5	**18.5**
		Total opening area (ft2)	346.3	346.3	**1731.5**
		Number of window units	19.2	19.2	**96**
		Number of doors	1.67	1.67	**8.35**
		Sheathing	plywood	plywood	**n/a**
		Stud thickness	2 x 4	2 x 4	**n/a**
		Stud Spacing	n/a	16 o/c	**n/a**
		Stud Type	kiln dried	kiln dried	**n/a**
5f) Add Walls (2)					
	A1 Stucco (2)				
		Wall Type	Exterior	Exterior	
		Length (ft)	104	104	**520**
		Height (ft)	18.5	18.5	**18.5**
		Total opening area (ft2)	346.3	346.3	**1731.5**
		Number of window units	19.2	19.2	**96**
		Number of doors	1.67	1.67	**8.35**
		Sheathing	plywood	plywood	**n/a**
		Stud thickness	2 x 4	2 x 4	**n/a**
		Stud Spacing	n/a	16 o/c	**n/a**
		Stud Type	kiln dried	kiln dried	**n/a**
5f) Add Walls (3)					
	A1 Stucco (3)				
		Wall Type	Exterior	Exterior	
		Length (ft)	104	104	**520**
		Height (ft)	18.5	18.5	**18.5**
		Total opening area (ft2)	346.3	346.3	**1731.5**
		Number of window units	19.2	19.2	**96**
		Number of doors	1.67	1.67	**8.35**
		Sheathing	plywood	plywood	**n/a**
		Stud thickness	2 x 4	2 x 4	**n/a**
		Stud Spacing	n/a	16 o/c	**n/a**
		Stud Type	kiln dried	kiln dried	**n/a**
5g) Add Walls					
	A1 first/second, Demising				
		Wall Type	Interior	Interior	
		Length (ft)	646	646	**3230**
		Height (ft)	18.4	18.4	**18.4**
		Total opening area (ft2)	n/a	n/a	**n/a**

		Number of window units	n/a	n/a	**n/a**
		Number of doors	20	20	**100**
		Sheathing	plywood	plywood	**n/a**
		Stud thickness	2 x 4	2 x 4	**n/a**
		Stud Spacing	n/a	16 o/c	**n/a**
		Stud Type	kiln dried	kiln dried	**n/a**
5h) Add Walls					
	A1 first/second, Inside Suite				
		Wall Type	Interior	Interior	
		Length (ft)	408	408	**2040**
		Height (ft)	18.4	18.4	**18.4**
		Total opening area (ft2)	n/a	n/a	**n/a**
		Number of window units	n/a	n/a	**n/a**
		Number of doors	20	20	**100**
		Sheathing	plywood	plywood	**n/a**
		Stud thickness	2 x 4	2 x 4	**n/a**
		Stud Spacing	n/a	16 o/c	**n/a**
		Stud Type	kiln dried	kiln dried	**n/a**
5i) Add Walls					
	A4 first/second, Demising				
		Wall Type	Interior	Interior	
		Length (ft)	221	221	**1105**
		Height (ft)	18.4	18.4	**18.4**
		Total opening area (ft2)	n/a	n/a	**n/a**
		Number of window units	n/a	n/a	**n/a**
		Number of doors	16	16	**80**
		Sheathing	plywood	plywood	**n/a**
		Stud thickness	2 x 4	2 x 4	**n/a**
		Stud Spacing	n/a	16 o/c	**n/a**
		Stud Type	kiln dried	kiln dried	**n/a**
5i) Add Walls (2)					
	A4 first/second, Demising (2)				
		Wall Type	Interior	Interior	
		Length (ft)	221	221	**1105**
		Height (ft)	18.4	18.4	**18.4**
		Total opening area (ft2)	n/a	n/a	**n/a**
		Number of window units	n/a	n/a	**n/a**
		Number of doors	16	16	**80**
		Sheathing	plywood	plywood	**n/a**
		Stud thickness	2 x 4	2 x 4	**n/a**
		Stud Spacing	n/a	16 o/c	**n/a**
		Stud Type	kiln dried	kiln dried	**n/a**
5j) Add Walls					
	A4 first/second, Inside Suite				
		Wall Type	Interior	Interior	
		Length (ft)	199	199	**995**
		Height (ft)	18.4	18.4	**18.4**
		Total opening area	n/a	n/a	**n/a**

		(ft2)			
		Number of window units	n/a	n/a	**n/a**
		Number of doors	20	20	**100**
		Sheathing	plywood	plywood	**n/a**
		Stud thickness	2 x 4	2 x 4	**n/a**
		Stud Spacing	n/a	16 o/c	**n/a**
		Stud Type	kiln dried	kiln dried	**n/a**
5k) Add Walls					
	A1 Third/Fourth, Demising				
		Wall Type	Interior	Interior	
		Length (ft)	722	722	**3610**
		Height (ft)	18.4	18.4	**18.4**
		Total opening area (ft2)	n/a	n/a	**n/a**
		Number of window units	n/a	n/a	**n/a**
		Number of doors	15	15	**75**
		Sheathing	plywood	plywood	**n/a**
		Stud thickness	2 x 4	2 x 4	**n/a**
		Stud Spacing	n/a	16 o/c	**n/a**
		Stud Type	kiln dried	kiln dried	**n/a**
5l) Add Walls					
	A1 Third/Fourth, Inside Suite				
		Wall Type	Interior	Interior	
		Length (ft)	476	476	**2380**
		Height (ft)	18.4	18.4	**18.4**
		Total opening area (ft2)	n/a	n/a	**n/a**
		Number of window units	n/a	n/a	**n/a**
		Number of doors	20	20	**100**
		Sheathing	plywood	plywood	**n/a**
		Stud thickness	2 x 4	2 x 4	**n/a**
		Stud Spacing	n/a	16 o/c	**n/a**
		Stud Type	kiln dried	kiln dried	**n/a**
5m) Add Walls					
	A4 Third, Demising				
		Wall Type	Interior	Interior	
		Length (ft)	21	21	**105**
		Height (ft)	9.2	9.2	**9.2**
		Total opening area (ft2)	n/a	n/a	**n/a**
		Number of window units	n/a	n/a	**n/a**
		Number of doors	20	20	**100**
		Sheathing	plywood	plywood	**n/a**
		Stud thickness	2 x 4	2 x 4	**n/a**
		Stud Spacing	n/a	16 o/c	**n/a**
		Stud Type	kiln dried	kiln dried	**n/a**
5n) Add Walls					
	A4 Third, Inside Suite				
		Wall Type	Interior	Interior	
		Length (ft)	108	108	**540**
		Height (ft)	9.2	9.2	**9.2**

		Total opening area (ft2)	n/a	n/a	**n/a**
		Number of window units	n/a	n/a	**n/a**
		Number of doors	20	20	**100**
		Sheathing	plywood	plywood	**n/a**
		Stud thickness	2 x 4	2 x 4	**n/a**
		Stud Spacing	n/a	16 o/c	**n/a**
		Stud Type	kiln dried	kiln dried	**n/a**
6a) Add Walls	Add Wood				
	Stairs				
		Volume (ft3)	240	240	**1200**
		Type	Kiln dried	Kiln dried	
6b) Add Walls	Add Concrete				
	1.5" floor toppings				
		Volume (ft3)	4700	4700	**23500**
		Type	n/a	4000psi	
Wall Summary					
AA) Add Walls					
	Exterior Walls				
	A4 Brick	Length	256		**1280**
	5 ext doors x 5 = 25	Height	21'		**21**
	A4 Stucco	Length	102		**510**
	15 ext doors = 75	Height	22'		**22**
	A1 Brick 1st and 2nd Floor	Length	764'		**3820**
	20 ext doors = 100	Height	18.5'		**18.5**
	A1 Brick 3rd and 4th Floor	Length	396'		**1980**
	36 ext doors = 180	Height	18.5'		**18.5**
	A1 Stucco	Length	312'		**1560**
	5 ext doors = 25	Height	18.5'		**18.5**
AB) Add Walls					
	Interior Walls				
	A1 first/second, Demising	Length	646'		**3230**
		Height	18.4'		**18.4**
	A1 first/second, Inside Suite	Length	408'		**2040**
		Height	18.4'		**18.4**
	A4 first/second, Demising	Length	442'		**2210**
		Height	18.4'		**18.4**
	A4 first/second, Inside Suite	Length	199		**995**
		Height	18.4'		**18.4**
	A1 Second/Third, Demising	Length	722		**3610**
		Height	18.4'		**18.4**
	A1 Second/Third, Inside Suite	Length	476'		**2380**
		Height	18.4'		**18.4**
	A4 Third, Demising	Length	21'		**105**

		Height	9.2'		**9.2**
	A4 Third, Inside Suite	Length	108'		**540**
		Height	9.2'		**9.2**

ANNEX “B” – IMPACT ESTIMATOR INPUT ASSUMPTIONS

General Assumptions

- The five almost identical blocks of the thunderbird residences have been modeled based on an analysis of one block, and then applied to the total area of the five blocks.

- Building A1 and A4 have been grouped together by their nature of construction and sharing of load path foundations, parkade, etc.

- As seen in the On-Screen quantity take-off, some measurements may have "half" noted in their descriptive name, referring to the fact that the building is symmetrical and this quantity is half of the actual quantity.

- Where multiple items have been referenced to one on-screen take-off, multiple reference numbers will be shown prior to the description.

- Assumption numbers (eg. "1a") correspond to same building components in the IE and On-Screen files

- The Commonsblock building was modeled as a residence building due to the fact that it was not included with the sample site 'A', which was the site of our specific analysis. It is, however, constructed in the same way as all the other residences, differing only in interior layout. For only this building, this analysis will slightly over-estimate the amount of interior partitioning per square foot. The Commonsblock building is different from the residences in that fact that it contains a fitness room, activity room and a music practice room

1) Foundations General

- To match available input selections in the IE, length, width and thickness measurements inputted into the IE were modified to reflect actual measured volume, not actual length, width, and thickness. The IE then takes this input information and then relates it back into a volume.
- Concrete flyash percentage was assumed as 'average' in the IE model as reflected by our regional construction practices, and building codes.
- Concrete strength was rounded up, when not accepted by the IE (eg. 3500Psi concrete not accepted, therefore 4000Psi concrete was used)

1a) Foundations – Spread Footings

All spread footing total volumes calculated based on the drawing specifications and "On-Screen" ("OS") data. Length, width and thickness inputted into the IE to reflect actual measured volume, not actual length, width, and thickness.

FOOTING SCHEDULE

MARK NO.	FOOTING SIZE	REINFORCING
F1	1000 X 1300 x 300 DEEP	5-15M 850 SHORT WAY BOTTOM 4-15M 1150 LONG WAY BOTTOM
F2	1200 x 1500 x 350 DEEP	6-15M 1050 SHORT WAY BOTTOM 5-15M 1350 LONG WAY BOTTOM
F3	1400 x 1700 x 400 DEEP	5-20M 1250 SHORT WAY BOTTOM 4-20M 1550 LONG WAY BOTTOM
F4	1600 x 1900 x 450 DEEP	7-20M 1450 SHORT WAY BOTTOM 6-20M 1750 LONG WAY BOTTOM
F5	1800 x 2100 x 500 DEEP	9-20M 1650 SHORT WAY BOTTOM 8-20M 1950 LONG WAY BOTTOM
F6	2000 X 2300 x 550 DEEP	11-20M 1850 SHORT WAY BOTTOM 9-20M 2150 LONG WAY BOTTOM
F7	2200 X 2500 x 600 DEEP	8-25M 2050 SHORT WAY BOTTOM 7-25M 2350 LONG WAY BOTTOM
F8	2400 X 2700 X 650 DEEP	10-25M 2250 SHORT WAY BOTTOM 9-25M 2550 LONG WAY BOTTOM
SF1	450 WIDE x 250 DEEP	2-15M CONT. DOWEL TO MATCH WALL VERTICAL

See the above schedule and OS count condition used to obtain 8748CF of concrete = 73' x 73' x 19.7" (arbitrary input dimensions to obtain correct volume)

1b) Foundations – Perimeter Footings

Length from OS 1b) condition, width and thickness from drawing 780-07-003 specifications as seen below:

SF1 450 WIDE x 250 DEEP 2-15M CONT.
DOWEL TO MATCH WALL VERTICAL

1c) Foundations – Perimeter Footings

392'x 172' found by using On-Screen dimension tool dwg 780-07-003

General check made from On-screen 1c)

1d) Foundations – Concrete Stairs

50% of building stairs assumed to be concrete based on the nature of construction, and lack of stair details

Stair area found and then multiplied by thickness

1750(1.10) SF x 0.5 ft (10% added for tread overlap), Stairs Concrete = 481 CF, Stairs Wood = 481 x (0.5) = 240 CF (factor of 0.5 assumed for volume of material usage comparison in wood and concrete construction of stairs), Concrete Total = 481CF = 20x48x0.5

1e) Foundations – Concrete Balconies

Balconies determined using the dimensioning tool on the upper floors ≈ 248LF x 6' x 6" + 20'x20' Platform (6" thickness). Total = (944 CF = 47.2x20x0.5)x2floors

2) Beams and Columns General

- Nomenclature: Built-up lumber columns = BU lumber columns
- Bay sizes, supported spans, and column types varied greatly throughout the structure without a grid pattern layout. Span and width dimensions were necessary for the IE inputs. In this case 20' Span and 20' bay widths are considered representative of the column and beam layout based on various average distances.
- No structural drawing displaying columns and beams for smaller building A4 were provided. As resolved through discussions with the project director, columns and beams were proportioned to A4 from the building A1 analysis based on area proportions.

2a) Beams and Columns - Parkade

Refer to general Beams and Columns assumptions listed above

Slab bands were inputted as beams

2b) Beams and Columns – First Floor

Refer to general Beams and Columns assumptions listed above

Add steel columns of first and second floor (2b&2c) together in the IE. Add PSL columns of first and second floor (2b&2c) together in the IE. As parameters are the same in both cases

eg. Steel columns = 90firstflr + 90secondflr = 180athena

2c) Beams and Columns – Second Floor

Refer to general Beams and Columns assumptions listed above

Steel columns of first and second floor (2b&2c) were added together in the IE. PSL columns of first and second floor (2b&2c) were added together in the IE. As parameters are the same in both cases.

2d) Beams and Columns – Third Floor

Refer to general Beams and Columns assumptions listed above

2e) Beams and Columns – Fourth Floor

Refer to general Beams and Columns assumptions listed above

Small height difference on fourth floor. Height was average based on using OS dimension tool.

<u>3) Floor System General</u>

- Span & width inputted into the IE to reflect actual measured area, not actual span and width.
- Concrete topping of applicable floors was added in Extra Basic Materials, 1.5" thickness

3a) Floor System – Structural First Floor

Refer to floor system general assumptions listed above

The parkade covers area under the courtyard that is not under building footprints. Therefore, the first floor concrete is computed under the buildings first floor footprints, and the remainder of suspended slab (under courtyard) above the parkade is computed as the parkade roof (Area 67,424SF-17,231SF = 50,193 SF)

4” polystyrene insulation assumed for this floor. Rigid insulation known, type of rigid insulation not known.

3b) Floor System – Structural Second Floor

Refer to floor system general assumptions listed above

1.5” Concrete floor topping added in 6b)

3c) Floor System – Structural Third Floor

Refer to floor system general assumptions listed above

Balconies added in part 1e)

3d) Floor System – Structural Fourth Floor

Refer to floor system general assumptions listed above

Balconies added in part 1e)

4) Roof System General

- Span & width inputted into the IE to reflect actual measured area, not actual span and width.
- Two storey roof applies to building A4, as the majority of this building is two storey
- Four storey roof applies to building A1, as the majority of this building is four storey

4a) Roof System – Two Storey Building

Refer to roof system general assumptions listed above

2-storey roof applies to building A4, as the majority of this building is 2-storey

Membrane type assumed to be common EPDM. Assumed that there is an additional 3 mil vapor barrier in addition to membrane roof system.

4b) Roof System – Four Storey Building

Refer to roof system general assumptions listed above

Built up roofing system assumed to be 4 ply – built-up roofing system (torch-down type)

1.2" Cellulose and glass felt envelope assumed for the BUR as no details provided on drawings.

4c) Roof System – Parkade

Refer to roof system general assumptions listed above

This input corresponds to the parkade roof area below the courtyard. Area = 67,424SF-17,231SF = 50,193SF . Small error between OS area dimension and 67,424 measured using dimension tool. The more accurate value of 67,424 was accepted to subtract the building footprint area from.

5) Wall System General

- A known issue in build 51 of the IE, was that windows and doors were limited at a maximum of 100 (each) per wall section in the IE. Many wall sections had greater than 100 doors/windows, therefore copies of these walls were made in the IE to accommodate this door and window restriction.
- Standard glazing was assumed for all windows, reflecting construction of 1995
- Windows were modeled based on two typical sample wall areas >1000 ft^2. The OS area and count conditions were used to determine the average amount of window fenestration per unit wall area. This method was made possible by the uniformity of fenestration throughout.
- Stud spacing not identified. Assumed to be that of typical residential wall construction 16" o/c
- Drawings state floor sheathing thickness, but not type. Sheathing type is assumed to be plywood.
- For stucco walls, stucco area was percentaged in certain areas to apply to areas lacking elevation drawings. This assumption was made in conjunction with an on-site inspection to confirm percentage break-ups.

5a) Wall System – Parkade

Refer to wall system general assumptions listed above

5a) and 5b) share window area to sum to 18% of wall area. The sum of window area 5a) and 5b) = 1927SF which is 18% of the wall area of 5a) and 5b) = 10,710SF

5b) Wall System – Building A4 Stucco

Refer to wall system general assumptions listed above

5a) and 5b) share window area to sum to 18% of wall area. The sum of window area 5a) and 5b) = 1927SF which is 18% of the wall area of 5a) and 5b) = 10,710SF

`5c) Wall System – Building A4 Brick

Refer to wall system general assumptions listed above

5d) Wall System – Building A1 Brick 1st and 2nd Floor

Refer to wall system general assumptions listed above

5e) Wall System – Building A1 Brick 3rd and 4th Floor

Refer to wall system general assumptions listed above

354 is total half wall length, 156 is half stucco wall length, so brick wall = (354LF-156LF)x 2 = 396LF

5f) Wall System – Building A1 Stucco

Refer to wall system general assumptions listed above

5g)-5n) Wall System – Interior walls

Refer to wall system general assumptions listed above

All interior doors dispersed among groups to make model accept them
Groups separated in excel in anticipation of model errors when adding doors greater than 100, however, model accepted doors greater than 100, so groupings of demising and inner suite walls were maintained. See last table on excel spreadsheet for inner building wall summary.

5) Extra Basic Materials

6a) Wooden Stairs

50% of building stairs assumed to be wood based on the nature of building construction, and lack of stair details

Stair area found and then multiplied by thickness

1750(1.10) SF x 0.5 ft (10% added for tread overlap), Stairs Concrete = 481 CF, Stairs Wood = 481 x (0.5) = 240 CF (factor of 0.5 assumed for volume of material usage comparison in wood and concrete construction of stairs), Concrete Total = 481CF = 20x48x0.5

6b) Concrete Floor Topping

Concrete floor topping 1.5" thick as per drawing specifications not accounted for in modeled floors from section 3 of this analysis

For second, third, and fourth floors.{17,231+10,812+4830(2)}SF x {1.5"/12) = 4700 CF. Concrete Strength is assumed to be 4000psi