Life Cycle Analysis – Fred Kaiser Building

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PROVISO

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

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

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In this report, Fred Kaiser Building was analyzed for life cycle assessment. This analysis includes quantity takeoff and data input by using OnScreen Takeoff and Athena Impact Estimator. TheOnScreen Takeoff Software creates a material list which includes the material type and quantities for data inputs in Athena Impact Estimator. The Impact Estimator uses the TRACI impact database to quantify the environmental impacts of the building assemblies.

The results of impact estimator include Bill of Materials and summary measures by life cycle stage and assembly group. The summary measures by life cycle stage showed eight categories of environmental impacts which are associated with the manufacturing stage of the building.

A sensitivity analysis was base on the five anticipated materials to investigate the relative impacts of each material overall environmental impact. It was determined that the most influential component out of the five chosen was the concrete with 30 MPa strength and average flyash.

In addition, an analysis was conducted to determine the amount of materials needed to improve the current buildings energy performance to UBC's Residential Environmental Assessment Program. Operating energy data was obtained from the UBC building services department and a spreadsheet template was used to determine the improvement of operating energy given material upgrades. It was determined that it will take approximately 36 months to recover the energy input for adding insulation materials from energy saving.

Contents

Tables

Figures

1.0 INTRODUCTION

Fred Kaiser Building is located at 2332 Main Mall, at the University Of British Columba (UBC), in Vancouver, Canada. The year of completion for this building is 2005 with a total cost of $26 million. The building consists of five floors and a basement with gross area of 136,303 square feet. Three top levels sit a portion of the old two-level civil and mechanical engineering (CEME) building that was constructed in the 1970s and the foundation had to under go significant seismic upgrades.

The use of this building includes Engineering Student Services, Technical Communication Centre, Faculty of Applied Science Dean's Office, Departments of Electrical and Computer Engineering, Mechanical Engineering.

The mainly applied structural materials in Kaiser Building were concrete and steel. Concrete was widely adopted for footings and walls in the foundations, interior walls, the roof, floors, and in the beams and columns. The steel was mainly used in columns and steel studs wall. The building envelope is primarily 4SSG Low E argon filled glass. The primary structural components of the building are described below in Table 1.

Building System	Specific Characteristics
Structure	Concrete columns and steel columns supporting floors
Floor	250mm suspended slab; 300mm suspended slab; 350mm suspended slab
Exterior wall	Predominantly Low E argon filled glass; concrete tilt-up
Interior wall	Mix of concrete block, cast in place and steel studs walls
Windows	Low E glass with aluminum windows frame
Roof	2 ply modified SBS roofing membrane; structural concrete slab, R-20 rigid insulation
Foundation	150mm slab on grade, concrete footings

Table 1 Building Characteristics

2.0 GOAL AND SCOPE

2.1 Goal of Study

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

The main outcomes of this LCA study are the establishment of a materials inventory and environmental impact references for the Kaiser building. An exemplary application of these references is in the assessment of potential future performance upgrades to the structure and envelope of the Kaiser building. When this study is considered in conjunction with the twenty-nine other UBC building LCA studies, further applications include the possibility of carrying out environmental performance comparisons across UBC buildings over time and between different materials, structural types and building functions. Furthermore, as demonstrated through these potential applications, this Kaiser building 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.

2.2 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 Fred Kaiser Building on a square foot finished floor area based on as built drawings. 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 Fred Kaiser Building, as well as associated transportation effects throughout.

2.3 Tools, Methodology and Data

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

The study will first undertake the initial stage of a materials quantity takeoff, which involves performing linear, area and count measurements of the building's structure and envelope. To accomplish this, OnScreen TakeOff version 3.7.0.11 is used, which is a software tool designed to perform material takeoffs with increased accuracy and speed in order to enhance the bidding capacity of its users.

Using imported digital plans, the program simplifies the calculation and measurement of the takeoff process, while reducing the error associated with these two activities. The measurements generated are formatted into the inputs required for the IE building LCA software to complete the takeoff process. These formatted inputs as well as their associated assumptions can be viewed in Annexes A and B respectively. Using the formatted takeoff data, version 4.0.64 of the IE software, the only available software capable of meeting the requirements of this study, is used to generate a whole building LCA model for Kaiser in the Vancouver region as an office 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 Fred Kaiser Building 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 Kaiser building, 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 Kaiser building. 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 when Fred Kaiser Building was initially constructed in 2005. The assemblies of the building that are modeled include the foundation, floors, walls (interior and exterior) 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 in the Building Model section and, as previously mentioned, all specific input related assumptions are contained in the Input Assumptions document in Appendix B.

3.0 BUILDING MODEL

3.1 Takeoffs

On-Screen Takeoff Software is the primary tool for completing the building materials quantity takeoff process. The takeoffs were performed on a set of digital drawings obtained from UBC campus planning and development office. Details of the interior and exterior walls are solely based on labels and information provided by the digital drawings. However, a noticeable amount of building elements which are not specified by the given drawing, are specified with reasonable assumptions, on-site observation and appropriate research. The components of the building are named as one type building system, followed by type of assemble, followed by actual labels specified in the drawing. The detailed analysis of procedures and assumptions for the quantity takeoffs are described as the following:

Walls

Exterior wall

The majority of the materials used for exterior walls are large low E argon filled glass panels. The list of typical and non typical glass panels is provided on the digital drawing 313-06-026; 313-06-027; 313-06-028. However, the glass materials cannot be specifically identified in the Impact Estimator. In order to convert to inputs for Impact Estimator, the glass panels are assumed to be viewable glazing consisting of a double glazed unit of two 6mm glazing panes with total thickness of 12mm. In addition, the observation on-site concludes that most glass panels are 90% to 100% glazing. The glazing was assumed to be 100% glazing to ensure consistency within the curtain wall materials.

The building envelope on the north and east side of the second floor of the building consists of both existing concrete walls left from old civil and mechanical building and new concrete walls. The new concrete wall is assembled by precast concrete panels, which is similar to concrete tilt-up available in Impact Estimator. The concrete strength is preferred to be 30MPa as it is the closest available option within the software. The existing exterior concrete walls are not within the cope of life cycle assessment since the quantity is relatively insignificant to the total impact analysis and the materials were not part of the manufacturing and construction for Fred Kaiser Building.

Windows in the curtain walls are specified as clear low E operable vents in the drawing, so they are input as Low E tin glazing operable in the Impact Estimator. All doors for the building envelope are observed closest to be aluminum exterior 80% glazing in the Impact Estimator.

Interior walls

The interior walls primarily consist of cast in place, concrete masonry units, and steel studs.The concrete properties of walls located in the basement are specified in the concrete properties schedule in the general notes of the drawing. The information for concrete reinforcement is adopted from reinforcement schedule in the general notes of the drawing. The type of concrete wall is not specified in the given drawing. Since foundation walls are mostly poured concrete for certain load bearing, cast in place wall is assumed in Impact Estimator.

Types of walls on the second, the third, the fourth, and the fifth floors are specified in the drawings. All concrete masonry unit walls are input as concrete blocks in the impact estimator. Steel studs wall information is input with good accordance to the drawing information. Studs weight, stud thickness and stud spacing are taken as interior walls. All 16mm gypsum wood boards are considered as 5/8” regular gypsum board. Wall20, 20a and 20b, are indicated as walls within the drawing but lack details information. The on-site observation concludes these types of wall are close to steel studs with gypsum boards. Drawing information which is outside the data range of Impact

Estimator will be assumed to the closest option available or averaged for input. Detailed assumptions for each type of wall are listed in Annex B

The thickness of different types of wall is obtained in two measures: manual measuring on the digital drawings by using on screen takeoffs; and obtaining from drawing information. The drawing information usually provides specific thickness for gypsum wood board, studs thickness and wood panel thickness. Thickness of concrete wall requires manual measurement on the drawing. However, this may result in a slight overestimation or underestimation of the wall thickness but is not expected to significantly affect the results of the impact analysis. The height of the wall was measured as distance between slab to slab on drawing No. 313-06-029. Since the height varies from slab to slab and mostly within in the range of 2.9 m and 3.3 m, the height of all interior walls is averaged 3.1 m. The names of types of wall used in Impact Estimator are in accordance with names indicated in the drawing.

The interior doors can be categorized into two main types: the doors for hallway are observed closest to steel interior door 50% glazing; the doors for offices and classrooms are observed closest to hollow core wood interior door. All walls and doors measured by linear condition and count condition respectively in Onscreen Takeoff.

Roofs

The roof was measured by using Area Condition in Onscreen Takeoff. The information regarding the roofs is specified in the digital drawing. However, there are three roof types identified in the building drawings, and they are named accordingly as R1, R2 and R3 in the roof type legend. Type R1 is specified as gravel ballast; 2 ply modified SBS roofing membrane; protection board; R-20 rigid insulation and structural concrete slab. Type R2 is specified as concrete pavers; The 2 ply modified SBS roofing membrane; protection board; R-20 rigid insulation and exterior sheathing; metal deck. Type R3 is specified as The 2 ply modified SBS roofing membrane; 16mm densedeck fireguard roof guard; R-20 Rigid insulation; vapor barrier;50mm concrete topping;

existing roof slab. Type R3A is similar to Type R3 in terms of assumptions therefore it is counted towards R3. The 2 ply modified SBS roofing membrane generally refer to polyester in between two asphalt layers (Claude).

Therefore, roofs were assumed accordingly as follows: suspended slab; and modified bitumen roofing system inverted with insulation of polylsocyanurate foam and polyethylene for vapor barrier in Impact Estimator. The concrete strength, fly ash percentage; and live loads are referred to general notes in drawing No. 313-07-001. The span of the roof was measured on the drawing and re-adjusted to be 9.75m for IE input. Detailed calculations and assumptions are available in Appendix B

There is a small portion of roof which consists of photovoltaic panels sandwiched in the atrium skylight (Robin). The materials of photovoltaic panels are not within the scope of Impact Estimator, and not accounted for overall impact analysis.

Floors

The spans for each floor were obtained by measuring distance between concrete columns by using On-Screen dimensioning tool. Due to a wide variety of the span size, the spans were averaged and re-adjusted to be within IE inputs limits. The concrete strength, fly ash percentage; and live loads are referred to general notes in drawing No. 313-07-001. The inputs of live load were with good accordance to the drawing information since the IE has available options for specified live loads.

The floor was identified as suspended floor with its measured thickness. The floors with similar thickness are measured together and averaged at a later time for column and beam inputs. The floor area was measured by using Area Condition in Onscreen Take off and it was purposed for readjustment of span size. However, the floor area was divided for few sections for measuring due to shape of the building. There could be some slight omission or overlapping of the area measurement but it generally complies with known floor areas of the building. Assumptions, Calculated span size and obtained concrete properties

Mixed Columns & Beams

The two main materials for columns are concrete and steel with various sizes and shapes. Assumption for beams is considered to be a challenging part of the takeoff process since information of beams is not available from the given available drawings. All column takeoffs are named according to column names given in the drawings.

The method used to measure column sizing was completely depended upon the metrics built into the Impact Estimator. The Impact Estimator calculates the sizing of beams and columns based on the following inputs; number of beams, number of columns, floor to floor height, bay size, supported span and live load. Being the case, since no beams were present in Fred Kaiser building, concrete columns were accounted for on each floor, while each floor's area was measured. The hollow structural steel (HSS) columns in the Kaiser building were located along the building envelope on each floor and columns for the fifth floor are all steel. The steel columns are modeled in the Extra Basic Materials, where their associated assumptions and calculations are documented in Appendix A and Appendix B.

Foundation

The Impact Estimator, slab-on-grade inputs are limited to being either a 100mm or 200mm thickness. Since the actual SOG thicknesses for the Kaiser building were not exactly 100mm or 200mm thick, the areas measured in OnScreen required calculations to adjust the areas to accommodate this limitation.

The Impact Estimator limits the thickness of footings to be between 190mm and 500mm thick. As there are a number of cases where footing thicknesses exceed 500mm, their areas were re-adjusted accordingly to maintain the same volume of footing while accommodating this limitation.

Lastly, the concrete stairs were modeled as footings (ie. Stairs_Concrete_Total Length). All stairs had the same thickness and width, so the total length of stair was measured and were combined into a single input.

Extra Basic Materials

The Hollow Structural Steel (HSS) columns were accounted for using count conditions for the different types. Using their cross sectional sizing, provided in the Steel Column Schedule in structural drawing 316-07-003, in conjunction with their height and per foot weight, referenced from the Steel Tube Institute, allowed for the calculation of the amount of HSS in weight for the columns. Detailed calculation for the weight of steel is available in Appendix B

All other materials such as plumbing systems and electrical systems as well as appliances and interior finishes such as ceiling, flooring, painting and landscaping materials were outside the scope of this project.

4.0 BILL OF MATERIALS

The Bill of Materials report was generated by Impact Estimator as the table below:

Material	Quantity	Unit
1/2" Regular Gypsum Board	238.7	m2
5/8" Regular Gypsum Board	20443.7464	m2
6 mil Polyethylene	5932.3745	m2
Aluminum	43.8275	Tonnes
Ballast (aggregate stone)	171633.735	kg
Batt. Fiberglass	2063.4474	m2 (25mm)

Concrete 30 MPa (flyash 25%)	2373.9736	m3
Concrete 30 MPa (flyash av)	4088.7629	m3
Concrete Blocks	31865.9139	Blocks
EPDM membrane	801.749	kg
Galvanized Sheet	2.7823	Tonnes
Galvanized Studs	28.3668	Tonnes
Glazing Panel	109.4841	Tonnes
Hollow Structural Steel	10.4939	Tonnes
Isocyanurate	11165.7423	m2 (25mm)
Joint Compound	20.6415	Tonnes
Low E Tin Glazing	176.75	m2
Modified Bitumen membrane	23852.0984	kg
Mortar	101.4029	m3
Nails	1.015	Tonnes
Paper Tape	0.2369	Tonnes
Polyethylene Filter Fabric	0.229	Tonnes
Rebar, Rod, Light Sections	411.3919	Tonnes
Screws Nuts & Bolts	2.9393	Tonnes
Small Dimension Softwood Lumber, kiln-dried	2.4365	m3
Softwood Plywood	1815.3068	m2 (9mm)
Solvent Based Alkyd Paint	6.8815	L
Water Based Latex Paint	131.7008	L
Welded Wire Mesh / Ladder Wire	2.849	Tonnes

Table 2 Bill of materials

The five largest amounts of materials in terms of the assembles to the amounts shown are 5/8" regular gypsum board (20443.7464 m2); concrete 30MPa fly ash average (4088.7629 m3); glazing panel (109.484 tons); rebar, rod, light sections (408.1176 tonnes; concrete blocks (31865.9139).

The regular gypsum board is most popular material used for interior walls and concrete wall envelopes within Fred Kaiser Building. The size of gypsum board is assumed to be all 5/8" thickness for consistency but there are also types of other materials which cannot be identified by IE such as wood board, and its thickness was rounded off to be 16 mm which could slight underestimate the quantity of the quantity of softwood and plywood.

Concrete 30MPa was widely used in the building. However, the measurement of its thickness and area can vary due to degree of accuracy of measuring by OnScreen tools. The assumption is slightly conservative and allowing small overestimation of the thickness to avoid omission of concrete materials. Therefore, the overall concrete quantity could be slightly over estimated in the Bill of Materials.

Glazing panel is the major portion for the building envelop. The height of the glazing panel on each floor is assumed to be the same as the floor to ceiling height for consistency, which could slight underestimate amount of glazing plane but it can be generally compensated by glazing panel on the fifth floor which has lower height of the panel due to framing and roof. Overall, the amount of glazing panel should be within the accepted range of errors for Bill of Materials.

Concrete blocks are important materials for interior walls are measured by linear conditions and it is an assumption made from concrete masonry units. However, mortar and cement were not calculated for the assumption due to limited information. The quantity of mortar could be slightly underestimated in Bill of materials.

Finally rebar, rod and light section inputs are mainly based on drawing information, but also not limited to assumption of average rebar size since certain rebar size is larger than the IE rebar size options. Therefore, it is possible that rebar is slight underestimated.

5.0 SUMMARY MEASURE

Energy Consumption

Energy consumptions generally refer to direct energy and indirect energy in all froms that used for building material manufacturing and transportation. Energy consumption is measured in mega joules (MJ) (Athena Institute, 2009). The energy consumption of Fred Kaiser Building is broken up by life-cycle stage in Figure 1. It shows that most of energy is consumed in the manufacturing stage.

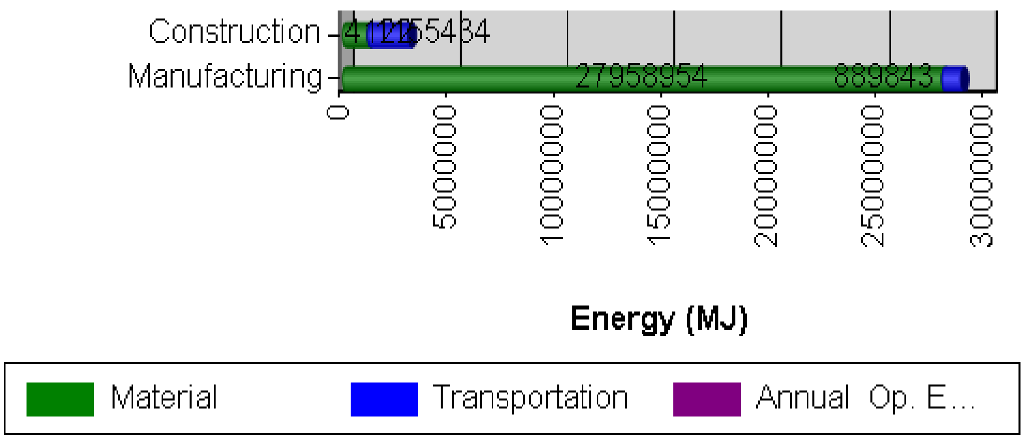

Figure 1 Energy

Acidification Potential

The acidification potential is expressed as a hydrogen ion equivalency based on mass balance calculations. Acidification is a predominately regional impact that can affect human health when NOX or SO2 reach high concentrations (Athena Institute,2009). The acidification potential of Fred Kaiser Building is broken up by life-cycle stage in Figure 2 below. Most of the NOX or SO2 is produced in the manufacturing process, and virtually exclusively due to the material production

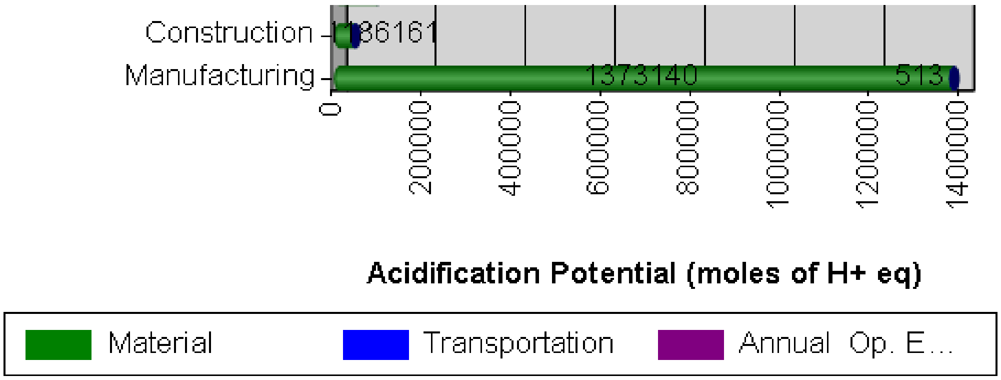

Figure 2 acidification potential

Global Warming Potential

Global Warming Potential is expressed in terms of CO2 equivalence by weight, since carbon dioxide is commonly recognized as greenhouse gas. The CO2 equivalence for other greenhouse gases is a ratio of the heat trapping potential to CO2, affected by a time horizon as different compounds have different reactivity in the atmosphere. The sources of greenhouse gas modeled include combustion for energy as well as processing of some raw resources such as in the production of concrete (Athena Institute, 2009). The global warming potential of Fred Kaiser Building is broken up by life-cycle stage as shown in Figure 3

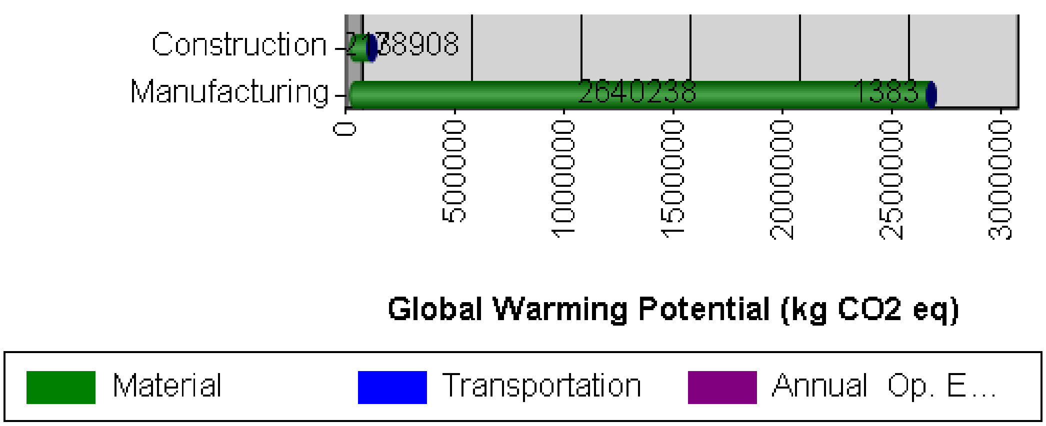

Figure 3 global warming potential

HH Respiratory Effects Potential

According to the United States Environmental Protection Agency (EPA), particulates, especially from diesel fuel combustion, can have a dramatic affect on human health due to respiratory problems such as asthma, bronchitis, and acute pulmonary disease. The Impact Estimator uses TRACI's "Human Health Particulates from Mobile Sources" characterization factor to account for the mobility of particles of different sizes, thus equivocated them to a single size: PM2.5 (Athena Institute, 2009). The human health respiratory effects potential of Kaiser is shown below in Figure 4, broken up by life-cycle stage.

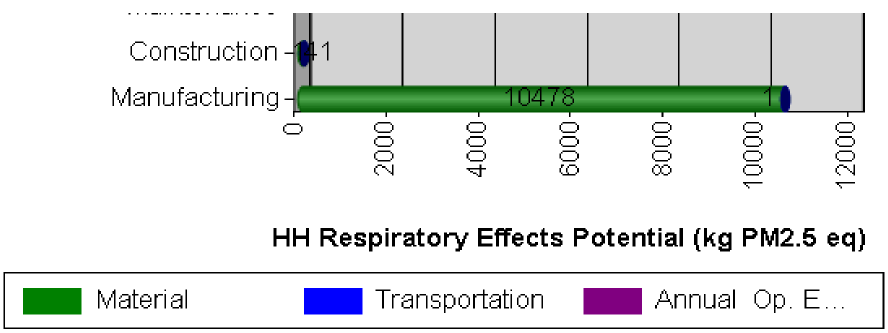

Figure 4 HH Respiratory Effects Potential

Ozone Depletion Potential

Ozone depletion has been a cause for global concern in the past. The ozone depletion potential is expressed in mass equivalence of CFC-11, based on their relative capacity to damage ozone in the stratosphere (Athena Institute, 2009). The ozone depletion potential of Fred Kaiser Building is broken up by life-cycle stage as shown in the figure below

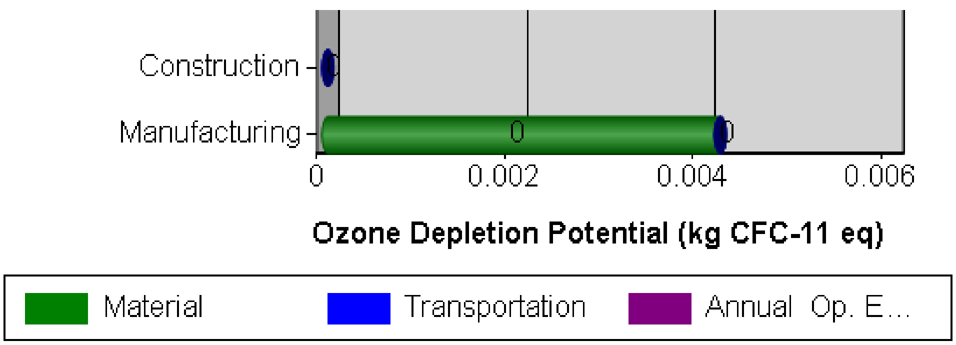

Figure 5 Ozone Depletion Potential

Smog Potential

Smog, or photochemical ozone creation potential, takes place under certain climate conditions when air emissions are trapped at ground level and are exposed to sunlight. The effect is actually a result of the interaction of volatile organic chemicals (VOCs) and nitrogen oxides and expressed in terms of mass of ethylene equivalence (Athena Institute, 2009). The smog potential of Fred Kaiser Building is broken up by life-cycle stage as shown in figure below

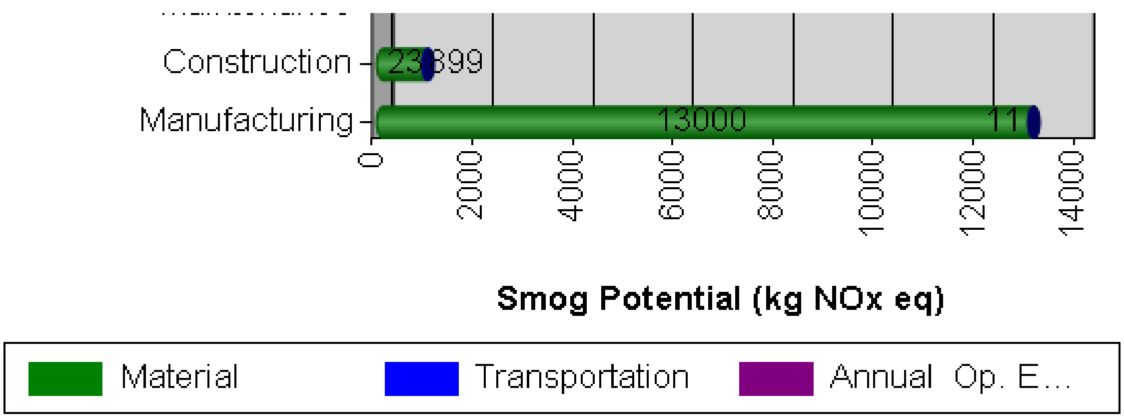

Figure 6 Smog Potential

Eutrophication Potential

Eutrophication potential is expressed in terms of mass equivalence of nitrogen (Athena Institute, 2009). When photosynthetic plant life such as algae proliferate, nutrients and oxygen are exhausted during certain period of time, which potentially harm aquatic life and/or producing other negative effects in the fish water habitat. The eutrophication potential of Fred Kaiser is broken up by life-cycle stage as shown below.

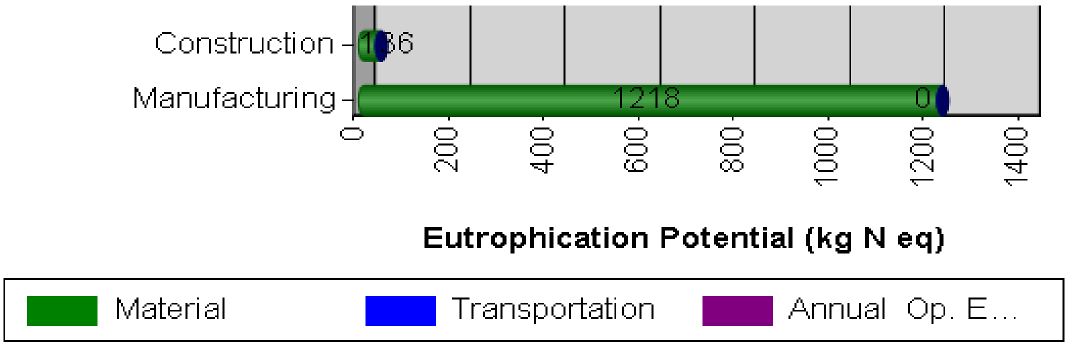

Figure 7 Eutrophication Potential

Weight Resource Use

Subjective weighting was studied and adopted with accordance to resource extraction and experts for the use of this software. The weighted resources include raw materials such as copper, iron ore, coal, and lumber. These weighted resources were factored and applied in the Impact Estimator's Bill of Materials. The results are expressed what can be thought of as "ecologically weighted kilograms" that represent relative levels of environmental impact based on expert opinion. The raw materials were used mainly at the manufacturing stage and the impact is reflected in the figure 8 below.

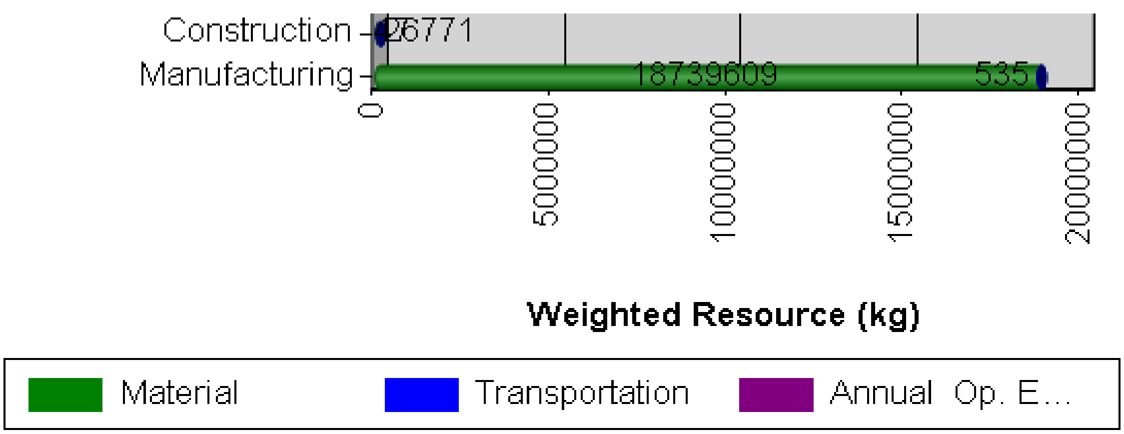

Figure 8 Weighted resources

Summary Measure Table

The table of summary measure in manufacturing, construction and end of life is listed below. Since the expected life of building is assumed to be one year, all other stages are not considered in the summary measure. The energy is in mega joule and the all other quantities are in equivalent kilogram. The results are shown below.

	Manufacturing		Construction		End - Of - Life		Total Effects
	Material	Transportation	Material	Transportation	Material	Transportation	
Primary Energy Consumption MJ	25816076.1	841654.9866	1168404.239	1772751.6	5791.743271	538250.0841	30142928.76
Weighted Resource Use kg	18925396.67	538.9645362	27071.32139	1157.064986	136.1422534	366.7608982	18954666.92
Global Warming Potential (kg CO2 eq)	2666112.161	1394.408661	79785.49303	3242.845436	377.0380854	1037.649065	2751949.595
Acidification Potential (moles of H+ eq)	1115111.552	483.6228924	36557.34849	1031.392849	20.90372548	327.2683696	1153532.088
HH Respiratory Effects Potential (kg PM2.5 eq)	10556.78914	0.583455294	41.30474929	1.239946926	0.019900016	0.393302993	10600.33049
Eutrophication Potential (kg N eq)	1226.848002	0.504020331	36.23373163	1.069021029	0.014353104	0.309181237	1264.978309
Ozone Depletion Potential (kg CFC-11 eq)	0.004209253	5.7497E-08	8.81563E-11	1.32808E-07	1.69861E-08	4.24864E-08	0.004209503
Smog Potential (kg NOx eq)	13111.06981	10.92377548	908.6570404	23.04033652	0.268604189	7.304462828	14061.26403

Table 3 Overall Summary measure

Uncertainties

The numbers shown in the summary measures table are not considered as absolutely accurate, but also accounts for uncertainties inherent within LCA. The Athena Impact Estimator uses average weighted values of products to come up with an environmental score (Athena Institute, 2009). The average value can result in overestimation or underestimation of the impacts. The assumptions of TRACI are that the impact of a product grows linearly proportional amount of the used product increases (Heijungs). This linear relationship does not reflect the actual relationship between impacts and material quantity which also accounts for other factors such as economy, capacity constraints. The detailed manufacturing information can be limited due to confidentiality for a private sector (Huijbregts). Imported products such as made-in-China are more difficult to be analyzed since they are not local products and information regarding manufacturing, transportation and environmental conditions is unknown or uncertain.

6.0 SENSITIVITY ANALYSIS

In sensitivity analyses, five important materials were chosen to study the effects of different materials on the overall impact of the building. The five materials are concrete 30MPa flyash average; concrete block; 5/8” regular gypsum board; glazing panel; rebar rod and light section. 10% of the chosen materials were added to the extra materials in the original models to compare with the impact of the original building. The focus of the study on these materials is solely on manufacturing and construction phases, since the impacts are most significant in these two phases.

Concrete Block

Concrete block was mainly used in the interior walls inside the building. Quantity of concrete block was increased by 10% in the original building. The table 4 shows that changes made on concrete block has relatively higher impact on energy consumption and global warming potential, ozone depletion potential and smog and acidification potential. It matches the facts that production of mortar and concrete masonry release greenhouse gases. However, the impact of concrete block is relatively insignificant to the overall impact of the building as shown in figure 9.

Add 10% Concrete Block	**% Difference**
Primary Energy Consumption	0.216%
Weighted Resource Use	0.014%
Global Warming Potential	0.248%
Acidification Potential	0.255%
HH Respiratory Effects Potential	0.192%
Eutrophication Potential	0.104%
Ozone Depletion Potential	0.246%
Smog Potential	0.203%

Table 4 Concrete block % difference

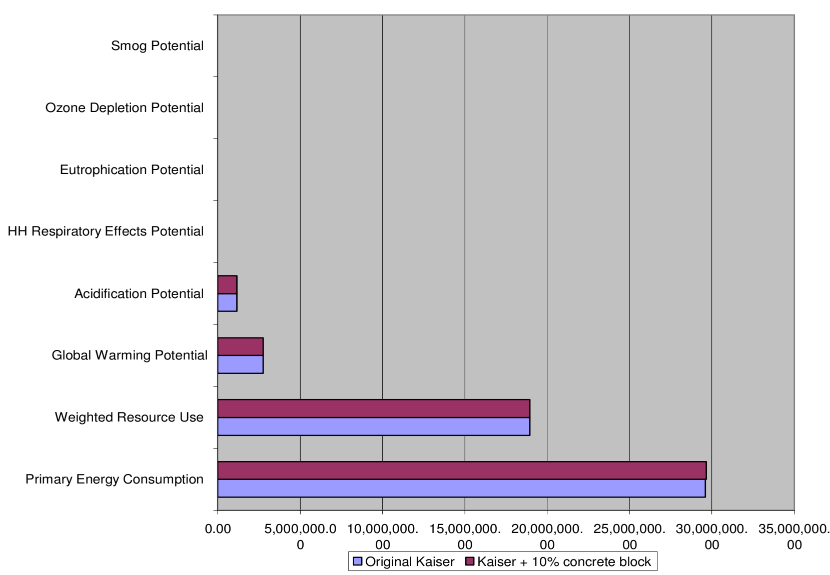

Figure 9 Addition of 10% concrete block

Concrete 30MPa with average fly ash

Concrete 30MPa average fly ash was mainly used in the interior walls inside the building. Quantity of concrete 30MPa was increased by 10% in the original building. The table 5 shows that changes made on concrete 30MPa has relatively higher impact on weighted resource use and global warming potential, ozone depletion potential and smog and acidification potential. It matches the facts that production of concrete requires raw materials of gravel and sand for concrete aggregates and the chemical process of the concrete curing releases green house gases. Overall, the impact of concrete block is relatively significant to the overall impact of the building as shown in figure 10

Add 10% Concrete 30MPa	% Difference
Primary Energy Consumption	2.49%
Weighted Resource Use	5.68%
Global Warming Potential	4.12%
Acidification Potential	3.92%
HH Respiratory Effects Potential	2.94%
Eutrophication Potential	2.17%
Ozone Depletion Potential	5.52%
Smog Potential	4.33%

Table 5 Concrete 30MPa % difference

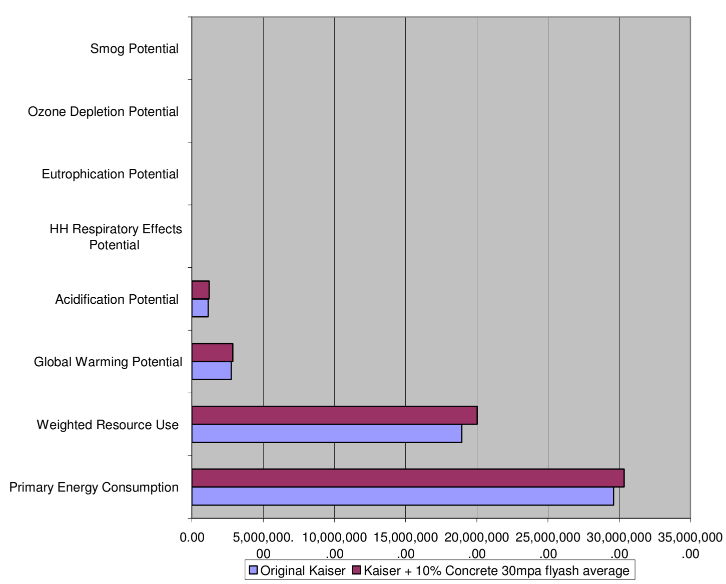

Figure 10 Addition of 10% concrete 30MPa with flyash average

5/8" Regular Gypsum Board

5/8" Regular Gypsum Board was mainly used in the interior walls inside the building. Quantity of 5/8" Regular Gypsum Board was increased by 10% in the original building. The table 6 shows that changes made 5/8" Regular Gypsum Board has relatively higher impact on primary energy consumption and global warming potential, HH Respiratory effects potential. However, the impact of concrete block is relatively significant to the overall impact of the building as shown in figure 11

Add 10% 5/8" Regular Gypsum Board	% Difference
Primary Energy Consumption	0.375%
Weighted Resource Use	0.126%
Global Warming Potential	0.224%
Acidification Potential	0.291%
HH Respiratory Effects Potential	0.263%
Eutrophication Potential	0.051%
Ozone Depletion Potential	0.003%
Smog Potential	0.077%

Table 6 Regular gypsum board % difference

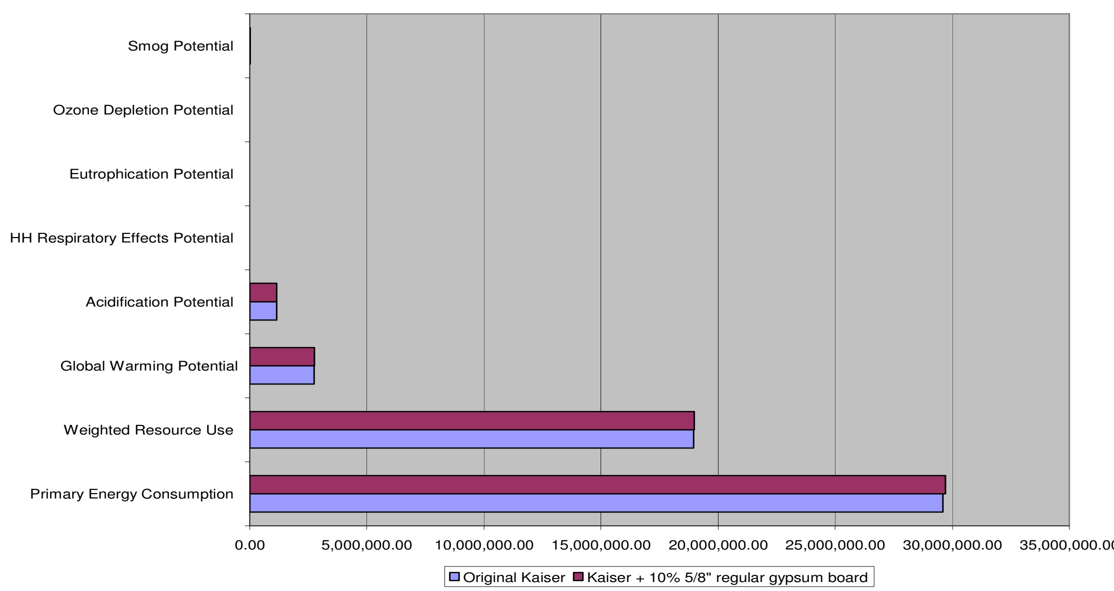

Figure 11 Addition of 10% regular gypsum board

Glazing Panel

Glazing panel was mainly used in the exterior walls outside the building. Quantity of glazing panel was increased by 10% in the original building. The table 7 shows that changes made glazing panel has relatively higher impact on global warming potential, smog potential, eutrophication potential, HH Respiratory effects potential. The results match the fact that the raw materials for glass making are all dusty material and are delivered either as a powder or as a fine-grained material, and the oxides of nitrogen are a natural product of the burning of gas in air and are produced in large quantities by gas fired furnaces (wiki) Overall, the impact of glazing panel is relatively significant to the HH Respiratory Effects Potential of the building as shown in figure 12.

Add 10% Glazing Panel	% Difference
Primary Energy Consumption	0.20%
Weighted Resource Use	0.12%
Global Warming Potential	0.68%
Acidification Potential	0.90%
HH Respiratory Effects Potential	2.66%
Eutrophication Potential	0.50%
Ozone Depletion Potential	0.17%
Smog Potential	0.81%

Table 7 Glazing panel % difference

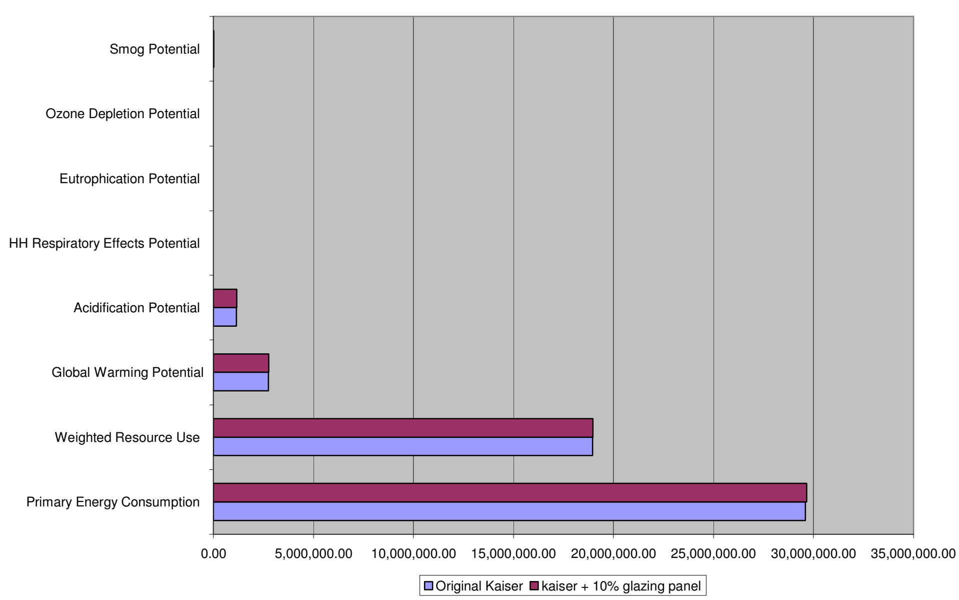

Figure 12 Addition of 10% glazing panel

Rebar Rod and Light Section

Rebar rod and light section was mainly used in walls, foundation footings, concrete labs in the building. Quantity of rebar rod and light section was increased by 10% in the original building. The table 8 shows that changes made rebar rod and light section has relatively higher impact on primary energy consumption, eutrophication potential. The results match the fact that the rebar are produced with high energy and the waste release contains nutrients into water. Overall, the impact of rebar rod and light section is relatively significant to primary energy consumption and eutrophication potential of the building as shown in figure 13

Add 10% Rebar Rod Light Section	% Difference
Primary Energy Consumption	2.67%
Weighted Resource Use	0.35%
Global Warming Potential	0.96%
Acidification Potential	0.77%
HH Respiratory Effects Potential	0.47%
Eutrophication Potential	4.07%
Ozone Depletion Potential	0.00%
Smog Potential	0.16%

Table 8 Rebar rod light section % difference

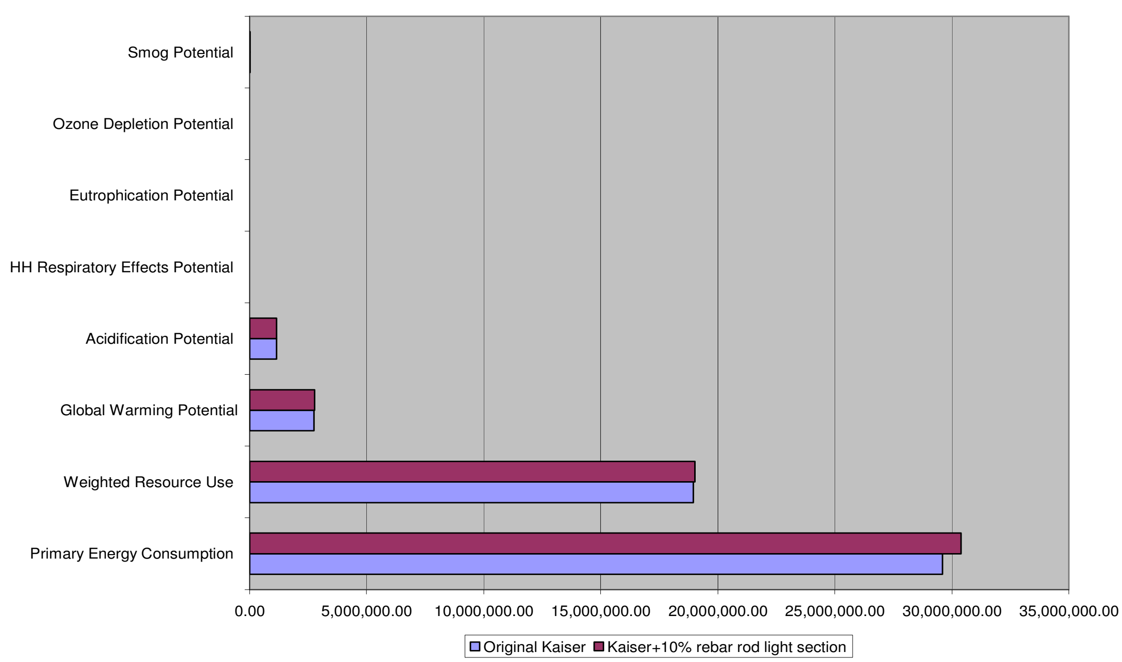

Figure13 Addition of 10% rebars rod light section

When performing life cycle analysis on the building, sensitivity analysis can be applied in the building design phase when decisions are made on material strengths and quantities. It can also facilitate decision making with regards to the building maintenance schedule and potential building upgrades. Design consultants and project manager would have a better understanding of the implications of alteration in material quantities on various summary measures.

7.0 BUILDING PERFORMANCE

Fred Kaiser Building was modeled as close as possible to its originality in the Impact Estimator. The R-value of insulations of roofs, exterior walls and windows were assigned according to the information of the drawing. The roofs generally have R-20 insulation as indicated in the drawing legend; windows are low E argon filled glazing; the insulation for concrete wall is assumed to be R-1. The insulations were modified to meet the Residential Environmental Assessment Program's (REAP) requirements, where minimum R-value for roof is 40; R-value for exterior wall Insulation is 18; minimum R-value for windows is 3.2 (UBC). In order to meet requirements, the walls were equipped with 2.36 inches foam polyisocyanurate with R-value of 7.2 and the roofs were equipped with 2.78 inches foam polyisocyanurate with R-value of 7.2 (Colorado).

The energy consumption for manufacturing and construction of the original Kaiser building was determined to be 36,356,885.2 Mega Joules. For the improved building, the energy consumption is increased to be 36961362.19 Megal Joules. The increase in energy consumption was related to addition of foam polyisocyanurate for insulating materials added to the building envelope. The R-value assigned to the windows and glazing panels is adequate enough to meet the REAP requirement.

The operating energy usage per year was calculated according to the heat loss equation $\mathbf{Q = A\ (\Delta T)/R}$ (2) where, R = Calculated R-Value in $ft^2\ {}^{o}F\ h/BTU$ (these are the

Imperial units); A = Assembly of interest ft^2; ΔT = Inside Temperature – Outside Temperature in ºF. The heat loss was calculated every month and accumulated over the year for total operating energy. The inside temperature was set to be (20□C); the outside temperature was based on historical average. The area of external exposure (A) was total area of the external wall; windows and roof. The R-value (R) used was the weighted average of the thermal resistance based on the surface area of the given medium.

The energy consumption for manufacturing and construction was input at time zero and was added by calculated yearly operating energy over 80 years. The trend of current energy consumption was plotted against the improved energy consumption, where the intersection point of the two is anticipated as energy pay-back period as shown in figure 14

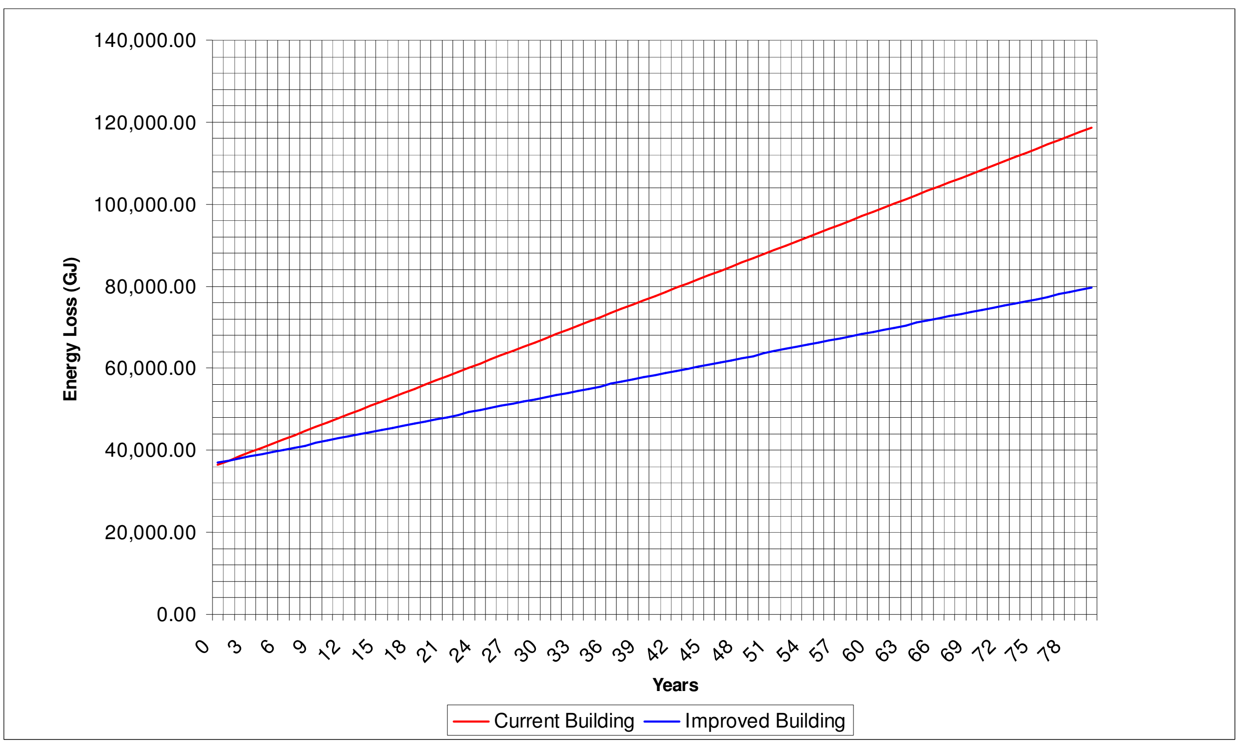

Figure 14 Comparison of building performance between current building and improved building

Payback period indicates the length of time for energy saved to recover energy invested in the improved building at manufacturing and construction stage. The figure() shows that the payback period is approximately 3 years. However, there are still uncertainties in the energy performance model and payback period calculations since the model is very basic and it does not account for window frame type and detailed information of the insulation. However, this model provides a general idea that the improvement on insulation of the building is recommended, since the building will begin to save energy yearly after short period time.

8.0 CONCLUSION

The life cycle assessment of Fred Kaiser Building was conducted by using OnScreen takeoffs and Athena Impact Estimator. The information regarding the building materials was mainly referred to the digital drawing from UBC campus planning and development office. The information inputs into Athena Impact Estimator were also based on assumptions under appropriate research, onsite observation and data round up. The input details and assumption are illustrated in Appendix A and B

The summary measures indicate that environmental impacts are significant at manufacturing and construction stages, where the primary energy consumption is 30142928.76 Mega Joules. The sensitivity analysis shows that input of concrete pour with 30MPa can easily affect the environmental impact assessment. Glazing panels can highly increase HH Respiratory effects potential. Rebar, rod and light section is also affects the primarily energy consumption largely with 10% quantity increase. The building performance was highly improved with addition of insulations. The initial primary energy invested in improvement can be recovered in approximately three years by the energy saved within the building.

However, Athena Impact Estimator is one of several tools for Life Cycle Assessment. The model created by the software is relatively basic and subject to change due to known and unknown uncertainties. The results provided by this study have noticeable significance in providing the audiences with a general view of the environmental impact. Meanwhile there are also other tools available for conducting LCA such as SimaPro, which can be used for comparing results for further study.

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Appendix A – Impact Estimator Input Tables

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 SOG_150mm			
			Length (m)	43.92	53.79
			Width (m)	43.92	53.79
			Thickness (mm)	150	100
			Concrete (MPa)	25	30
			Concrete flyash %	50%	average
	1.2 Concrete Footing				
		1.2.1 Footing_F1			
			Length (m)	0.9	0.9
			Width (m)	0.9	0.90
			Thickness (mm)	300	300
			Concrete (MPa)	25	30
			Concrete flyash %	50	average
			Rebar	20M	20M
		1.2.2 Footing_F2			

			Length (m)	1.2	1.2
			Width (m)	1.2	1.20
			Thickness (mm)	300	300
			Concrete (MPa)	25	30
			Concrete flyash %	50	average
			Rebar	20M	20M
		1.2.3. Footing_F3			
			Length (m)	1.5	1.5
			Width (m)	1.5	1.5
			Thickness (mm)	400	400
			Concrete (MPa)	25	30
			Concrete flyash %	50	average
			Rebar	20M	20M
		1.2.4 Footing_F4			
			Length (m)	1.75	1.84
			Width (m)	1.75	1.84
			Thickness (mm)	550	500
			Concrete (MPa)	25	30
			Concrete flyash %	50	average
			Rebar	20M	20M
		1.2.5 Footing_F5			
			Length (m)	2	2.19
			Width (m)	2	2.19
			Thickness (mm)	600	500

			Concrete (MPa)	25	30
			Concrete flyash %	50	average
			Rebar	20M	20M
		1.2.6 Footing_F6			
			Length (m)	2.25	2.66
			Width (m)	2.25	2.66
			Thickness (mm)	700	500
			Concrete (MPa)	25	30
			Concrete flyash %	50	average
			Rebar	20M	20M
		1.2.7 Footing_F7			
			Length (m)	2.85	3.6
			Width (m)	2.85	3.6
			Thickness (mm)	800	500
			Concrete (MPa)	25	30
			Concrete flyash %	50	average
			Rebar	25M	20M
		1.2.8 Footing_F8			
			Length (m)	1.6	2.5
			Width (m)	2.8	0.00
			Thickness (mm)	700	500
			Concrete (MPa)	25	30
			Concrete flyash %	50	average
			Rebar	25M	20M

1.2.9 Footing_F9			
	Length (m)	**1.6**	**2.86**
	Width (m)	**3.2**	**2.86**
	Thickness (mm)	**800**	**500**
	Concrete (MPa)	**25**	**30**
	Concrete flyash %	**50**	**average**
	Rebar	**25M**	**20M**
1.2.10 Footing_F10			
	Length (m)	**1.6**	**3.036**
	Width (m)	**5**	**3.036**
	Thickness (mm)	**900**	**500**
	Concrete (MPa)	**25**	**30**
	Concrete flyash %	**50**	**average**
	Rebar	**25M**	**20M**
1.2.11 Footing_F11			
	Length (m)	**1.2**	**2.4**
	Width (m)	**3**	**2.4**
	Thickness (mm)	**800**	**500**
	Concrete (MPa)	**25**	**30**
	Concrete flyash %	**50**	**average**
	Rebar	**25M**	**20M**
1.2.12 Footing_F12			
	Length (m)	**1.9**	**2.68**

			Width (m)	2.7	2.68
			Thickness (mm)	700	500
			Concrete (MPa)	25	30
			Concrete flyash %	50	average
			Rebar	25M	20M
		1.2.13 Footing_F13			
			Length (m)	2.7	3.367
			Width (m)	3	3.367
			Thickness (mm)	700	500
			Concrete (MPa)	25	30
			Concrete flyash %	50	average
			Rebar	25M	20M
		1.2.14 Footing_F14			
			Length (m)	0.7	0.77
			Width (m)	0.7	0.77
			Thickness (mm)	600	500
			Concrete (MPa)	25	30
			Concrete flyash %	50	average
			Rebar	25M	20M
		1.2.15 Footing_F16			
			Length (m)	0.45	0.45
			Width (m)	0.45	0.45
			Thickness (mm)	250	250
			Concrete (MPa)	25	30

			Concrete flyash %	50	average
			Rebar	15M	15M
		1.2.16 Footing_F17			
			Length (m)	0.6	0.6
			Width (m)	0.6	0.6
			Thickness (mm)	450	450
			Concrete (MPa)	25	30
			Concrete flyash %	50	average
			Rebar	20M	20M
		1.2.17 Footing_F18			
			Length (m)	0.90	0.90
			Width (m)	0.90	0.90
			Thickness (mm)	450.00	450
			Concrete (MPa)	25	30
			Concrete flyash %	50	average
			Rebar	20M	20M
		1.2.18 Footing_F19			
			Length (m)	0.45	0.45
			Width (m)	0.45	0.45
			Thickness (mm)	250.00	250
			Concrete (MPa)	25	30
			Concrete flyash %	50	average
			Rebar	15M	15M
		1.2.19 Footing_F20			

			Length (m)	**0.60**	**0.60**
			Width (m)	**0.60**	**0.60**
			Thickness (mm)	**300.00**	**300**
			Concrete (MPa)	**25**	**30**
			Concrete flyash %	**50**	**average**
			Rebar	**15M**	**15M**
		1.2.20 Footing_SF			
			Length (m)	**0.45**	**0.45**
			Width (m)	**0.45**	**0.45**
			Thickness (mm)	**250.00**	**250**
			Concrete (MPa)	**25**	**30**
			Concrete flyash %	**50**	**average**
			Rebar	**15M**	**15M**
		1.2.21 Stairs_Concrete_TotalLength			
			Length (m)	**54**	**54**
			Width (m)	**2**	**4.8**
			Thickness (mm)	**0.48**	**0.48**
			Concrete (MPa)	**25**	**30**
			Concrete flyash %	**50**	**average**
			Rebar	**15M**	**15M**
2 Walls					
	2.1 Cast In Place				

		2.1.1 Wall_Cast-in-Place_CW4_440mm			
			Length (m)	**12**	**12.00**
			Height (m)	**3.1**	**4.55**
			Thickness (mm)	**440**	**300**
			Concrete (MPa)	**25**	**30**
			Concrete flyash %	**40**	**average**
			Rebar	**15M**	**15M**
		2.1.2 Wall_Cast-in-Place_CW5_517mm			
			Length (m)	**19**	**19**
			Height (m)	**3.1**	**5.34**
			Thickness (mm)	**517**	**300**
			Concrete (MPa)	**25**	**30**
			Concrete flyash %	**40**	**average**
			Rebar	**20M**	**20M**
		2.1.3 Wall_Cast-In-Place_CW6_612mm			
			Length (m)	**14**	**14**
			Height (m)	**3.1**	**6.324**
			Thickness (mm)	**612**	**300**
			Concrete (MPa)	**25**	**30**

			Concrete flyash %	40	average
			Rebar	20M	20M
		2.1.4 Wall_Cast-in-Place_Partition_300mm			
			Length (m)	59	59
			Height (m)	3.10	3.10
			Thickness (mm)	300	300
			Concrete (MPa)	25	30
			Concrete flyash %	40	average
			Rebar	20M	20M
		2.1.5 Wall_Cast-in-Place_perimeter wall_220mm			
			Length (m)	233	233
			Height (m)	3.1	2.27
			Thickness (mm)	220	300
			Concrete (MPa)	25	30
			Concrete flyash %	40	average
			Rebar	20M	20M
	2.2 Concrete Block Wall				
		2.2.1 Wall_ConcreteBlock_W01_407mm			

		Door Opening	Length (m)	63	63
			Height (m)	3.1	3.1
			Rebar	15M	15M
			Number of Doors	4	4
			Door Type	-	Steel Interior Door, 50% glazing
		2.2.2 Wall_ConcreteBlock_W02_410mm			
		Door Opening	Length (m)	447	447
			Height (m)	3.1	3.1
			Rebar	15M	15M
			Number of Doors	23	23
			Door Type	-	Steel Interior Door, 50% glazing
		2.2.3 Wall_ConcreteBlock_W03_472mm			
		Door Opening	Length (m)	33	33
			Height (m)	3.1	3.1
			Rebar	15M	15M
			Number of Doors	1	1
			Door Type	-	Steel Interior Door, 50% glazing

		Steel Studs				
		Envelope	Length (m)	33	33
			Height (m)	3.1	3.1
			Stud Spacing	-	400 O.C
			Stud Weight	-	Light (25Ga)
			Stud Thickness	-	39x92
			Sheathing Type	-	None
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
			Thickness (mm)	16	16
		2.2.4 Wall_ConcreteBlock_W06_230mm			
		Door Opening	Length (m)	47	47
			Height (m)	3.1	3.1
			Rebar	15M	15M
			Number of Doors	3	3
			Door Type	-	Steel Interior Door, 50% glazing
		2.2.5 Wall_ConcreteBlock_W07_442mm			
			Length (m)	50	50

		Door Opening	Height (m)	3.1	3.1
			Rebar	15M	15M
			Number of Doors	0	0
			Door Type	-	Steel Interior Door, 50% glazing
		Steel Studs			
		Envelope	Length (m)	33	33
			Height (m)	3.1	3.1
			Stud Spacing	-	400 O.C
			Stud Weight	-	Light (25Ga)
			Stud Thickness	-	39x92
			Sheathing Type	-	None
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
			Thickness (mm)	16	16
		2.2.6 Wall_ConcreteBlock_W05_445mm			
		Door Opening	Length (m)	6	6
			Height (m)	3.1	3.1
			Rebar	15M	15M
			Number of Doors	1	1

			Door Type	**-**	**Steel Interior Door, 50% glazing**
		Steel Studs			
		Envelope	**Length (m)**	**6**	**6**
			Height (ft)	**3.1**	**3.1**
			Stud Spacing	**400 O.C**	**400 O.C**
			Stud Weight	**-**	**Light (25Ga)**
			Stud Thickness	**-**	**39x92**
			Sheathing Type	**-**	**None**
			Category	**Gypsum Board**	**Gypsum Board**
			Material	**Gypsum Regular 5/8"**	**Gypsum Regular 5/8"**
			Thickness (mm)	**16**	**16**
			Sheathing Type	**-**	**None**
			Category	**Gypsum Board**	**Gypsum Board**
			Material	**Gypsum Regular 5/8"**	**Gypsum Regular 5/8"**
			Thickness (mm)	**16**	**16**
		2.2.7 Wall_ConcreteBlock_W05a_445mm			
			Length (m)	**6**	**6**
			Height (m)	**3.1**	**3.1**
			Rebar	**15M**	**15M**

		Door Opening	**Number of Doors**	**3**	**1**
			Door Type	**-**	**Steel Interior Door, 50% glazing**
		Steel Studs			
		Envelope	**Length (m)**	**6**	**6**
			Height (ft)	**3.1**	**3.1**
			Stud Spacing	**400 O.C**	**400 O.C**
			Stud Weight	**-**	**Light (25Ga)**
			Stud Thickness	**-**	**39x92**
			Sheathing Type	**-**	**None**
			Category **Material** **Thickness (mm)**	**Insulation acoustic insulation** **50**	**Insulation Fiberglass Batt** **50**
			Category **Material** **Thickness (mm)**	**Gypsum Board** **Gypsum Regular 5/8"** **16**	**Gypsum Board** **Gypsum Regular 5/8"** **16**
		2.2.8 Wall_ConcreteBlock_W05b_445mm			
			Length (m)	**86**	**86**
			Height (m)	**3.1**	**3.1**
			Rebar	**15M**	**15M**
		Door Opening	**Number of Doors**	**3**	**3**

			Door Type	**-**	**Steel Interior Door, 50% glazing**
		Steel Studs			
		Envelope	**Length (m)**	**86**	**86**
			Height (ft)	**3.1**	**3.1**
			Stud Spacing	**400 O.C**	**400 O.C**
			Stud Weight	**-**	**Light (25Ga)**
			Stud Thickness	**-**	**39x92**
			Sheathing Type	**-**	**None**
			Category	**Gypsum Board**	**Gypsum Board**
			Material	**Gypsum Regular 5/8"**	**Gypsum Regular 5/8"**
			Thickness (mm)	**16**	**16**
		2.2.9 Wall_ConcreteBlock_W18a_232mm			
		Door Opening	**Length (m)**	**11**	**11**
			Height (m)	**3.1**	**3.1**
			Rebar	**15M**	**15M**
			Number of Doors	**0**	**0**
			Door Type	**-**	**Steel Interior Door, 50% glazing**
		Steel Studs			

			Length (m)	11	11
			Height (m)	3.1	3.1
			Stud Spacing	400 O.C	400 O.C
			Stud Weight	-	Light (25Ga)
			Stud Thickness	-	39x92
			Sheathing Type	-	None
		Envelope	Category	Gypsum Board	Gypsum Board
			Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
			Thickness (mm)	16	16
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
			Thickness (mm)	16	16
	2.3 Curtain Wall				
		2.3.1 Wall_CurtainWall_Georgianwireglass			
			Length (m)	3	3
			Height (m)	3.1	3.1
			Percent Viewable Glazing	100	100
			Percent Spandrel Panel	0	0

			Thickness of Insulation (mm)	**12**	**12**
			Spandrel Type (Metal/Glass)	**glass**	**glass**
		2.3.2 Wall_CurtainWall _clear glass screen			
			Length (m)	**96**	**96**
			Height (m)	**3.1**	**3.1**
			Percent Viewable Glazing	**100**	**100**
			Percent Spandrel Panel	**0**	**0**
			Thickness of Insulation (mm)	**12**	**12**
			Spandrel Type (Metal/Glass)	**glass**	**glass**
		Door Opening	**Number of Doors**	**17**	**17**
			Door Type	**-**	**Aluminum Exterior Door, 80% glazing**
		2.3.2 Wall_CurtainWall _W8.1			
			Length (m)	**254**	**254**
			Height (m)	**3.1**	**3.1**

			Percent Viewable Glazing	100	100
			Percent Spandrel Panel	0	0
			Thickness of Insulation (mm)	12	12
			Spandrel Type (Metal/Glass)	glass	glass
		Door Opening	Number of Doors	10	10
			Door Type	-	Aluminum Exterior Door, 80% glazing
		2.3.2 Wall_CurtainWall_W8.2			
			Length (m)	459	459
			Height (m)	3.1	3.1
			Percent Viewable Glazing	100	100
			Percent Spandrel Panel	0	0
			Thickness of Insulation (mm)	12	12
			Spandrel Type (Metal/Glass)	glass	glass
		Door Opening	Number of Doors	4	4

		Windows	Door Type	-	Aluminum Exterior Door, 80% glazing
			Number of windows	143	143
			Total Windows Area(m^2)	1.00	1
			Glazing	Low E Operable	Low E Tin Glazing Operable
			Frame Type	-	Aluminum Exterior Door, 80% glazing
		2.3.2 Wall_CurtainWall _W8.3			
			Length (m)	210	210
			Height (m)	3.1	3.1
			Percent Viewable Glazing	100	100
			Percent Spandrel Panel	0	0
			Thickness of Insulation (mm)	-	6
			Spandrel Type (Metal/Glass)	glass	glass
		Door Opening	Number of Doors	4	4

		Windows	**Door Type**	**-**	**Aluminum Exterior Door, 80% glazing**
			Number of windows	**32**	**32**
			Total Windows Area(m^2)	**1.00**	**1**
			Glazing	**Low E Operable**	**Low E Tin Glazing Operable**
			Frame Type	**-**	**Aluminum Exterior Door, 80% glazing**
	2.4 Steel Stud				
		2.4.1 Wall_SteelStud_Wall09			
		Door Opening	**Length (m)**	**1374**	**1374**
			Height (m)	**3.1**	**3.1**
			Sheathing Type	**-**	**None**
			Stud Spacing	**400 O.C**	**400 O.C**
			Stud Weight	**-**	**Light (25Ga)**
			Stud Thickness	**92**	**39x92**
			Number of Doors	**74**	**74**
			Door Type	**-**	**Hollow Core Wood Interior Door**

		Envelope	**Category**	**Gypsum Wood Board**	**Gypsum Board**
			Material	**-**	**Gypsum Regular 5/8"**
			Thickness(mm)	**16**	**16**
			Category	**Gypsum Wood Board**	**Gypsum Board**
			Material	**-**	**Gypsum Regular 5/8"**
			Thickness(mm)	**16**	**16**
		2.4.2 Wall_SteelStud_ Wall09a			
			Length (m)	**64**	**64**
			Height (m)	**3.1**	**3.1**
			Sheathing Type	**None**	**None**
			Stud Spacing	**400 O.C**	**400 O.C.**
			Stud Weight	**-**	**Light (25Ga)**
			Stud Thickness	**92**	**39x92**
		Door Opening	**Number of Doors**	**1**	**1**
			Door Type	**-**	**Hollow Core Wood Interior Door**
		Envelope	**Category**	**Insulation**	**Insulation**
			Material	**acoustic insulation**	**Fiberglass Batt**
			Thickness (mm)	**50**	**50**
			Category	**Gypsum Wood Board**	**Gypsum Wood Board**

			Material	GWB	Gypsum Regular 5/8"
			Thickness	-	-
			Category	Gypsum Board	Gypsum Board
			Material	-	Gypsum Regular 5/8"
			Thickness (mm)	16	16
		2.4.3 Wall_SteelStud_Wall09b			
			Length (m)	80	80
			Height (m)	3.1	3.1
			Sheathing Type	None	None
			Stud Spacing	400 O.C	400 O.C.
			Stud Weight	-	Light (25Ga)
			Stud Thickness	92	39x92
		Door Opening	Number of Doors	3	3
			Door Type	-	Hollow Core Wood Interior Door
		Envelope	Category	Insulation	Insulation
			Material	acoustic insulation	Fiberglass Batt
			Thickness (mm)	80	80
			Category	Gypsum Wood Board	Gypsum Wood Board
			Material	GWB	Gypsum Regular 5/8"

			Thickness	16	16
			Category Material Thickness (mm)	Gypsum Board GWB 16	Gypsum Board Gypsum Regular 5/8'' 16
		2.4.4 Wall_SteelStud_ Wall09c			
		Envelope	Length (m)	70	70
			Height (m)	3.1	3.1
			Sheathing Type	-	None
			Stud Spacing	400 O.C	400 O.C
			Stud Weight	-	Light (25Ga)
			Stud Thickness	92	39x92
			Category Material Thickness(mm)	Gypsum Wood Board GWB 16	Gypsum Board Gypsum Regular 5/8'' 16
			Category Material Thickness(mm)	Gypsum Wood Board - 16	Gypsum Board Gypsum Regular 5/8'' 16
		2.4.5 Wall_SteelStud_wall17			
			Length (m)	323	323

			Height (m)	3.1	3.1
			Sheathing Type		None
			Stud Spacing	600 O.C.	600 O.C.
			Stud Weight	-	Light (25Ga)
			Stud Thickness	101mm	39x92
		Door Opening	Number of Doors	8	8
			Door Type	-	Hollow Core Wood Interior Door
		Envelope	Category	Shalf wall liner	Gypsum Board
			Material		Gypsum Regular 5/8"
			Thickness (mm)	25	25
			Category	Gypsum Board	Gypsum Board
			Material		Gypsum Regular 5/8"
			Thickness (mm)	16	16
		2.4.6 Wall_SteelStud_wall22			
			Length (m)	13	13
			Height (m)	3.1	3.1
			Sheathing Type		None
			Stud Spacing	400 O.C	400 O.C.
			Stud Weight	-	Light (25Ga)

			Stud Thickness	92 mm	39x92
		Door Opening	Number of Doors	1	1
			Door Type	-	Hollow Core Wood Interior Door
		Envelope	Category Material	Insulation acoustic insulation	Insulation Fiberglass Batt
			Thickness (mm)	100	100
			Category	Gypsum Board	Gypsum Board
			Material	GWB	Gypsum Regular 5/8"
			Thickness (mm)	16	16
			Category	Gypsum Board	Gypsum Board
			Material	GWB	Gypsum Regular 5/8"
			Thickness (mm)	16	16
		2.4.7 Wall_SteelStud_wall22a			
			Length (m)	43	43
			Height (m)	3.1	3.1
			Sheathing Type		None
			Stud Spacing	400 O.C	400 O.C.
			Stud Weight	-	Light (25Ga)
			Stud Thickness	92 mm	39x92
		Door Opening	Number of Doors	24	24

			Door Type	-	Hollow Core Wood Interior Door
		Envelope	Category Material Thickness (mm)	Insulation acoustic insulation 50	Insulation Fiberglass Batt 50
			Category Material Thickness (mm)	Gypsum Board GWB 16	Gypsum Board Gypsum Regular 5/8" 16
			Category Material Thickness (mm)	Gypsum Board GWB 16	Gypsum Board Gypsum Regular 5/8" 16
		2.4.8 Wall_SteelStud_wall24			
			Length (m)	176	176
			Height (m)	3.1	3.1
			Sheathing Type		None
			Stud Spacing	400 O.C	400 O.C.
			Stud Weight	-	Light (25Ga)
			Stud Thickness	92 mm	39x92
		Door Opening	Number of Doors	15	15
			Door Type	-	Hollow Core Wood Interior Door

		Envelope	Category	Gypsum Board	Gypsume Board
			Material	Wood panel	Gypsum Regular 5/8"
			Thickness (mm)	19	16
			Category	Gypsum Board	Gypsum Board
			Material	GWB	Gypsum Regular 5/8"
			Thickness (mm)	16	16
			Category	Gypsum Board	Gypsum Board
			Material	GWB	Gypsum Regular 5/8"
			Thickness (mm)	16	16
		2.4.9 Wall_SteelStud_wall13			
			Length (m)	16	16
			Height (m)	3.1	3.1
			Sheathing Type	-	None
			Stud Spacing	-	400 O.C.
			Stud Weight	-	Light (25Ga)
			Stud Thickness	92 mm	39x92
		Envelope	Category	Gypsum Board	Gypsume Board
			Material	GWB	Gypsum Regular 5/8"
			Thickness (mm)	16	16

2.4.10 Wall_SteelStud_wall26			
Envelope	Length (m)	292	292
	Height (m)	3.1	3.1
	Sheathing Type	plywood	plywood
	Stud Spacing	400 O.C	400 O.C.
	Stud Weight	-	Light (25Ga)
	Stud Thickness	92 mm	39x92
	Category	Gypsum Board	Gypsum Board
	Material	GWB	Gypsum Regular 5/8"
	Thickness (mm)	16	16
	Category	Gypsum Board	Gypsum Board
	Material	GWB	Gypsum Regular 5/8"
	Thickness (mm)	16	16
	Category	Gypsum Board	Gypsum Board
	Material	GWB	Gypsum Regular 5/8"
	Thickness (mm)	16	16
2.4.11 Wall_SteelStud_wall27			
	Length (m)	40	40
	Height (m)	3.1	3.1
	Sheathing Type	Birch Plywood	plywood

			Stud Spacing	400 O.C	400 O.C.
			Stud Weight	-	Light (25Ga)
			Stud Thickness	92 mm	39x92
		Envelope	Category	Gypsum Board	Gypsum Board
			Material	GWB	Gypsum Regular 5/8"
			Thickness (mm)	16	16
			Category	Gypsum Board	Gypsum Board
			Material	GWB	Gypsum Regular 5/8"
			Thickness (mm)	16	16
		2.4.12 Wall_SteelStud_ Wall20			
			Length (m)	18	18
			Height (m)	3.1	3.1
			Sheathing Type	-	None
			Stud Spacing	400 O.C	400 O.C
			Stud Weight	-	Light (25Ga)
			Stud Thickness	92	39x92
		Envelope	Category	Gypsum Wood Board	Gypsum Board
			Material	GWB	Gypsum Regular 5/8"
			Thickness(mm)	16	16

			Category	Gypsum Wood Board	Gypsum Board
			Material	-	Gypsum Regular 5/8"
			Thickness(mm)	16	16
		2.4.13 Wall_SteelStud_ Wall20a			
			Length (m)	256	256
			Height (m)	3.1	3.1
			Sheathing Type	-	None
			Stud Spacing	400 O.C	400 O.C
			Stud Weight	-	Light (25Ga)
			Stud Thickness	92	39x92
		Door Opening	Number of Doors	62	62
			Door Type	-	Hollow Core Wood Interior Door
		Envelope	Category	Gypsum Wood Board	Gypsum Board
			Material	GWB	Gypsum Regular 5/8"
			Thickness(mm)	16	16
			Category	Gypsum Wood Board	Gypsum Board
			Material	-	Gypsum Regular 5/8"
			Thickness(mm)	16	16

		2.4.14 Wall_SteelStud_ Wall20b			
		Envelope	Length (m)	9	9
			Height (m)	3.1	3.1
			Sheathing Type	-	None
			Stud Spacing	400 O.C	400 O.C
			Stud Weight	-	Light (25Ga)
			Stud Thickness	92	39x92
			Category	Gypsum Wood Board	Gypsum Board
			Material	GWB	Gypsum Regular 5/8"
			Thickness(mm)	16	16
			Category	Gypsum Wood Board	Gypsum Board
			Material	-	Gypsum Regular 5/8"
			Thickness(mm)	16	16
3 Columns and Beams					
	3.1 Concrete Column				
		3.1.1 Column_Concrete _Beam_Basement			
			Number of Beams		

			Number of Columns	**71**	**71**
			Floor to floor height (m)	**3.1**	**3.1**
			Bay sizes (m)	**6.14**	**6.14**
			Supported span (m)	**6.14**	**6.14**
			Live load (MPa)	**4.8**	**4.8**
		3.1.2 Column_Concrete _Beam_GroundLe vel			
			Number of Beams	**94**	**94**
			Number of Columns	**94**	**94**
			Floor to floor height (m)	**5.34**	**5.34**
			Bay sizes (m)	**5.34**	**5.34**
			Supported span (m)	**9.75**	**9.75**
			Live load (MPa)	**4.8**	**4.8**
		3.1.3 Column_Concrete _Beam_Level2			
			Number of Beams	**43**	**43**
			Number of Columns	**43**	**43**

			Floor to floor height (m)	**3.1**	**3.1**
			Bay sizes (m)	**5.14**	**5.14**
			Supported span (m)	**5.14**	**5.14**
			Live load (MPa)	**3.6**	**3.6**
		3.1.4 Column_Concrete _Beam_Level3			
			Number of Beams	**69**	**69**
			Number of Columns	**69**	**69**
			Floor to floor height (m)	**3.1**	**3.1**
			Bay sizes (m)	**6.23**	**6.23**
			Supported span (m)	**6.23**	**6.23**
			Live load (MPa)	**3.6**	**3.6**
		3.1.5 Column_Concrete _Beam_Level4			
			Number of Beams	**44**	**44**
			Number of Columns	**44**	**44**
			Floor to floor height (m)	**3.1**	**3.1**
			Bay sizes (m)	**5.42**	**5.42**

			Supported span (m)	**5.42**	**5.42**
			Live load (MPa)	**R**	**3.6**
4 Floors					
	4.1 Concrete Suspended Slab				
		4.1.1 SBS_250mm			
			Floor Width (m)	**405.91**	**549.54**
			Span (m)	**13.2**	**9.75**
			Concrete (MPa)	**25**	**30**
			Concrete flyash %	**25**	**25**
			Live load (Kpa)	**4.8**	**4.8**
		4.1.2 SBS_300mm			
			Floor Width (m)	**288.79**	**390.97**
			Span (m)	**13.20**	**9.75**
			Concrete (MPa)	**25**	**30**
			Concrete flyash %	**25**	**25**
			Live load (Kpa)	**3.6**	**3.6**
		4.1.3 SBS_350mm			
			Floor Width (m)	**98.03**	**132.72**
			Span (m)	**13.20**	**9.75**
			Concrete (MPa)	**25**	**30**
			Concrete flyash %	**25**	**25**

			Life load (Kpa)	3.6	3.6
5 Roof					
	5.1 Concrete Suspended Slab				
		5.1.1 Roof_ConcreteSuspendedSlab_R1			
		Envelope	Roof Width (m)	39	156
			Span (m)	39	9.75
			Concrete (MPa)	30	30
			Concrete flyash %	25	average
			Life load (MPa)	0.8	0.8
			Category	Roof Envelopes	Roof Envelopes
			Material	2 ply modified sbs roofing membrane	Modified Bitumen Membrane 2 ply
			Thickness	-	-
			Category	Insulation	Insulation
			Material	R-20 Rigid insulaiton	Polyisocyanurate Foam
			Thickness(mm)	-	100.00
			Category	Vapour Barrier	Vapour Barrier
			Material	-	Polyethylene 6 mil
			Thickness	-	-
			Category	Roof Envelopes	Roof Envelopes

			Material Thickness	Gravel Ballast	Ballast 25.381
		5.1.2 Roof_ConcreteSuspendedSlab_R2			
		Envelope	Roof Width (m)	33.53	115.28
			Span (m)	33.53	9.75
			Concrete (MPa)	30	30
			Concrete flyash %	25	average
			Life load (MPa)	0.8	0.8
			Category Material Thickness	Roof Envelopes 2 ply modified sbs roofing membrane -	Roof Envelopes Modified Bitumen Membrane 2 ply -
			Category Material Thickness(mm)	Insulation R-20 Rigid insulaiton -	Insulation Polyisocyanurate Foam 100.00
			Category Material Thickness	Vapour Barrier - -	Vapour Barrier Polyethylene 6 mil -
		5.1.3 Roof_ConcreteSuspendedSlab_R3			

			Roof Width (m)	7.35	5.54
			Span (m)	7.35	9.75
			Concrete (MPa)	30	30
			Concrete flyash %	25	average
			Life load (MPa)	0.8	0.8
		Envelope	Category	Roof Envelopes	Roof Envelopes
			Material	2 ply modified sbs roofing membrane	Modified Bitumen Membrane 2 ply
			Thickness	-	-
			Category	Insulation	Insulation
			Material	R-20 Rigid insulaiton/100 mm rigid insulation	Polyisocyanurate Foam
			Thickness(mm)	-	100.00
			Category	Vapour Barrier	Vapour Barrier
			Material	-	Polyethylene 6 mil
			Thickness	-	-
6 Extra Basic Materials					
	6.1 Steel				
		6.1.1 XBM_Columns_HSS_(Total Sum)			

			Hollow Structural Steel (Tons)	**-**	**10.39**

Appendix B Impact Estimator Input Assumption

Assembly Group	**Assembly Type**	**Assembly Name**	**Specific Assumptions**
1 Foundation	**The Impact Estimator, SOG inputs are limited to being either a 100mm or 200mm thickness. Since the actual SOG thicknesses for the Kaiser building were not exactly 100mm or 200mm thick, the areas measured in OnScreen required calculations to adjust the areas to accommodate this limitation. The Impact Estimator limits the thickness of footings to be between 190mm and 500mm thick. As there are a number of cases where footing thicknesses exceed 500mm , their areas were re-adjusted accordingly to maintain the same volume of footing while accommodating this limitation. Lastly, the concrete stairs were modelled as footings (ie. Stairs_Concrete_TotalLength). All stairs had the same thickness and width, so the total length of stair was measured and were combined into a single input.**		
	1.1 Concrete Slab-on-Grade		
		1.1.1 SOG_150mm	**The area of this slab had to be adjusted so that the thickness fit into the 4" thickness specified in the Impact Estimator. The following calculation was done in order to determine appropriate Length and Width (in feet) inputs for this slab; = sqrt[((Measured Slab Area) x (Actual Slab Thickness))/(4"/12)] = sqrt[(1929m^2 x (0.15m))/(0.1)] = 53.8m**
	1.2 Concrete Footi		

ng		
	1.2.4 Footing_F4	**The area of this footing was adjusted to accommodate the Impact Estimator limitation of footing thicknesses to be under 500mm. The length and widths were re-adjusted and equal by using the following calculations;** **= SQRT[(Cited Width)x(Cited Length) x (Cited Thickness)/ (0.5)]** **= SQRT(1.75*1.75*0.55/0.5)** **= 1.84m**
	1.2.5 Footing_F5	**The area of this footing was adjusted to accommodate the Impact Estimator limitation of footing thicknesses to be under 500mm. The length and widths were re-adjusted and equal by using the following calculations;** **= SQRT[(Cited Width)x(Cited Length) x (Cited Thickness)/ (0.5)]** **= SQRT(2*2*0.6/0.5)** **= 2.19m**
	1.2.6 Footing_F6	**The area of this footing was adjusted to accommodate the Impact Estimator limitation of footing thicknesses to be under 500mm. The length and widths were re-adjusted and equal by using the following calculations;** **= SQRT[(Cited Width)x(Cited Length) x (Cited Thickness)/ (0.5)]** **= SQRT(2.25*2.25*0.7/0.5)** **= 2.66m**

		1.2.7 Footing_F7	**The area of this footing was adjusted to accommodate the Impact Estimator limitation of footing thicknesses to be under 500mm. The length and widths were re-adjusted and equal by using the following calculations;** **= SQRT[(Cited Width)x(Cited Length) x (Cited Thickness)/ (0.5)]** **= SQRT(2.85*2.85*0.8/0.5)** **= 3.6m**
		1.2.8 Footing_F8	**The area of this footing was adjusted to accommodate the Impact Estimator limitation of footing thicknesses to be under 500mm. The length and widths were re-adjusted and equal by using the following calculations;** **=SQRT[(Cited Width)x(Cited Length) x (Cited Thickness)/ (0.5)]** **= SQRT(1.6*2.8*0.7/0.5)** **= 2.5m**
		1.2.8 Footing_F8	**The area of this footing was adjusted to accommodate the Impact Estimator limitation of footing thicknesses to be under 500mm. The length and widths were re-adjusted and equal by using the following calculations;** **=SQRT[(Cited Width)x(Cited Length) x (Cited Thickness)/ (0.5)]** **= SQRT(1.6*2.8*0.7/0.5)** **= 2.5m**

		1.2.9 Footing_F9	**The area of this footing was adjusted to accommodate the Impact Estimator limitation of footing thicknesses to be under 500mm. The length and widths were re-adjusted and equal by using the following calculations;** **=SQRT[(Cited Width)x(Cited Length) x (Cited Thickness)/ (0.5)]** **= SQRT(1.6*3.2*0.8/0.5)** **= 2.86m**
		1.2.10 Footing_F10	**The area of this footing was adjusted to accommodate the Impact Estimator limitation of footing thicknesses to be under 500mm. The length and widths were re-adjusted and equal by using the following calculations;** **=SQRT[(Cited Width)x(Cited Length) x (Cited Thickness)/ (0.5)]** **= SQRT(1.6*3.2*0.9/0.5)** **= 3.036m**
		1.2.10 Footing_F10	**The area of this footing was adjusted to accommodate the Impact Estimator limitation of footing thicknesses to be under 500mm. The length and widths were re-adjusted and equal by using the following calculations;** **=SQRT[(Cited Width)x(Cited Length) x (Cited Thickness)/ (0.5)]** **= SQRT(1.6*3.2*0.9/0.5)** **= 3.036m**

		1.2.11 Footing_F11	**The area of this footing was adjusted to accommodate the Impact Estimator limitation of footing thicknesses to be under 500mm. The length and widths were re-adjusted and equal by using the following calculations;** **=SQRT[(Cited Width)x(Cited Length) x (Cited Thickness)/ (0.5)]** **= SQRT(1.2*3*0.8/0.5)** **= 2.4m**
		1.2.12 Footing_F12	**The area of this footing was adjusted to accommodate the Impact Estimator limitation of footing thicknesses to be under 500mm. The length and widths were re-adjusted and equal by using the following calculations;** **=SQRT[(Cited Width)x(Cited Length) x (Cited Thickness)/ (0.5)]** **= SQRT(1.9*2.7*0.7/0.5)** **= 2.68m**
		1.2.13 Footing_F13	**The area of this footing was adjusted to accommodate the Impact Estimator limitation of footing thicknesses to be under 500mm. The length and widths were re-adjusted and equal by using the following calculations;** **=SQRT[(Cited Width)x(Cited Length) x (Cited Thickness)/ (0.5)]** **= SQRT(2.7*3*0.7/0.5)** **= 3.367m**

		1.2.14 Footing_F14	The area of this footing was adjusted to accommodate the Impact Estimator limitation of footing thicknesses to be under 500mm. The length and widths were re-adjusted and equal by using the following calculations; =SQRT[(Cited Width)x(Cited Length) x (Cited Thickness)/ (0.5)] = SQRT(0.7*0.7*0.6/0.5) = 0.7m
		1.2.15 Stairs_Concrete_TotalLength/Thickness	The thickness of the stairs was estimateded to be 480mm based on the cross-section structural drawing and adjusted to 200mm to assumed to be slab on grade
2 Walls	The length of the concrete cast-in-place walls needed adjusting to accommodate the wall thickness limitation in the Impact Estimator. It was assumed that interior steel stud walls were light gauge (25Ga) and exterior steel stud walls were heavy gauge (20Ga). The concrete strength is assumed to be 30MPa.		
	2.1 Cast In Place		

		2.1.1 Wall_Cast-in-Place_CW4_440mm	**This wall height was increased by a factor in order to fit the 300mm thickness limitation of the Impact Estimator. This was done by increasing the height of the wall using the following equation;** **= (Measured Length*Measured Height) * [(Cited Thickness)/[Measured L *300]** **= (12*3.1*0.44)/(12*0.3)** **= 4.55m**
		2.1.2 Wall_Cast-in-Place_CW5_517mm	**This wall height was increased by a factor in order to fit the 300mm thickness limitation of the Impact Estimator. This was done by increasing the height of the wall using the following equation;** **= (Measured Length*Measured Height) * [(Cited Thickness)/[Measured L *300]** **= (19*3.1*0.517)/(19*0.3)** **= 5.34m**
		2.1.3 Wall_Cast-In-Place_CW6_612mm	**This wall height was increased by a factor in order to fit the 300mm thickness limitation of the Impact Estimator. This was done by increasing the height of the wall using the following equation;** **= (Measured Length*Measured Height) * [(Cited Thickness)/[Measured L *300]** **=(14*3.1*0.612)/(14*0.3)** **= 6.32m**

		2.1.5 Wall_Cast-in-Place_Perimeter wall_220mm	This wall height was increased by a factor in order to fit the 300mm thickness limitation of the Impact Estimator. This was done by increasing the height of the wall using the following equation; = (Measured Length*Measured Height) * [(Cited Thickness)/[Measured L *300] =(233*3.1*0.22)/(233*0.3) = 2.27m
	2.2 Concrete Block Wall		
		2.2.1 Wall_ConcreteBlock_W01_407mm	Steel Interior Door with 50% glazing was the closest estimtation to the observed doors in this wall.
		2.2.2 Wall_ConcreteBlock_W02_410mm	Steel Interior Door with 50% glazing was the closest estimtation to the observed doors in this wall.
		2.2.3 Wall_ConcreteBlock_W03_472mm	Steel Interior Door with 50% glazing was the closest estimtation to the observed doors in this wall.
		2.2.4 Wall_ConcreteBlock_W06_230mm	Steel Interior Door with 50% glazing was the closest estimtation to the observed doors in this wall.

		2.2.5 Wall_ConcreteBlock_W07_442mm	Steel Interior Door with 50% glazing was the closest estimtation to the observed doors in this wall.
		2.2.6 Wall_ConcreteBlock_W05_445mm	Steel Interior Door with 50% glazing was the closest estimtation to the observed doors in this wall.
		2.2.7 Wall_ConcreteBlock_W05a_445mm	Steel Interior Door with 50% glazing was the closest estimtation to the observed doors in this wall.
		2.2.8 Wall_ConcreteBlock_W05b_445mm	Steel Interior Door with 50% glazing was the closest estimtation to the observed doors in this wall.
		2.2.9 Wall_ConcreteBlock_W18a_232mm	Steel Interior Door with 50% glazing was the closest estimtation to the observed doors in this wall.
	2.3 Curtain Wall		
		2.3.1 Wall_CurtainWall_Georgianwireglass	Georgianwire glass is assumed to be Curtain wall100% glazing glass spantrel panel

		2.3.2 Wall_CurtainWall_clear glass screen	**Clear glass is assumed to be Curtain wall100% glazing glass spantrel panel**
		2.3.3 Wall_CurtainWall_W8.1	**Aluminum Door with 80% glazing was the closest estimtation to the observed doors in this wall.**
		2.3.4 Wall_CurtainWall_W8.2	**Aluminum Door with 80% glazing was the closest estimtation to the observed doors in this wall.**
		2.3.5 Wall_CurtainWall_W8.3	**Aluminum Door with 80% glazing was the closest estimtation to the observed doors in this wall. The windows are Low E clear glass so Low E tin glazing is the closet assumtion**
	2.4 Steel Stud		
		2.4.1 Wall_SteelStud_Wall 09	**The doors are observed closest to be hollow core interior door. The gypsum on bohth sides was assumed to be of the same specifications as 5/8" Regular Gypsum**
		2.4.2 Wall_SteelStud_Wall 09a	**The doors are observed closest to be hollow core interior door. The gypsum on bohth sides was assumed to be of the same specifications as 5/8" Regular Gypsum. Acoustic Batt insulation was not available in the Impact Estimator so Fiberglass Batt was selected as the closest surrogate.**

		2.4.3 Wall_SteelStud_Wall 09b	**The doors are observed closest to be hollow core interior door. The gypsum on bohth sides was assumed to be of the same specifications as 5/8" Regular Gypsum. Acoustic Batt insulation was not available in the Impact Estimator so Fiberglass Batt was selected as the closest surrogate.**
		2.4.4 Wall_SteelStud_Wall 09c	**The gypsum on bohth sides was assumed to be of the same specifications as 5/8" Regular Gypsum. Acoustic Batt insulation was not available in the Impact Estimator so Fiberglass Batt was selected as the closest surrogate.**
		2.4.5 Wall_SteelStud_Wall17	**The doors are observed closest to be hollow core interior door. The shaft line is assumed closest to be gypsum wood board. The gypsum on both sides was assumed to be of the same specifications as 5/8" Regular Gypsum**
		2.4.5 Wall_SteelStud_Wall22	**The doors are observed closest to be hollow core interior door. The gypsum on bohth sides was assumed to be of the same specifications as 5/8" Regular Gypsum. Acoustic Batt insulation was not available in the Impact Estimator so Fiberglass Batt was selected as the closest surrogate.**
		2.4.5 Wall_SteelStud_Wall22a	**The doors are observed closest to be hollow core interior door. The gypsum on both sides was assumed to be of the same specifications as 5/8" Regular Gypsum. Acoustic Batt insulation was not available in the Impact Estimator so Fiberglass Batt was selected as the closest surrogate.**

		2.4.5 Wall_SteelStud_Wall24	**The doors are observed closest to be hollow core interior door. The gypsum on bohth sides was assumed to be of the same specifications as 5/8" Regular Gypsum.**
		2.4.9 Wall_SteelStud_Wall13	**The gypsum on bohth sides was assumed to be of the same specifications as 5/8" Regular Gypsum.**
		2.4.10 Wall_SteelStud_Wall26	**The gypsum on bohth sides was assumed to be of the same specifications as 5/8" Regular Gypsum. Since there is no plywood option in Impact Estimator, 5/8" Regular Gypsum is the closest assumption**
		2.4.11 Wall_SteelStud_Wall27	**The gypsum on bohth sides was assumed to be of the same specifications as 5/8" Regular Gypsum. Since there is no birch plywood option in Impact Estimator, 5/8" Regular Gypsum is the closest assumption**
		2.4.12 Wall_SteelStud_Wall20	**The wall is assumed to be steel studes with gypusm wood boards**
		2.4.13 Wall_SteelStud_Wall20a	**The wall is assumed to be steel studes with gypusm wood boards**
		2.4.14 Wall_SteelStud_Wall20b	**The wall is assumed to be steel studes with gypusm wood boards**

<table>
<tr><td rowspan="4">3 Columns and Beams</td><td colspan="3">The method used to measure column sizing was completely depended upon the metrics built into the Impact Estimator. That is, the Impact Estimator calculates the sizing of beams and columns based on the following inputs; number of beams, number of columns, floor to floor height, bay size, supported span and live load. This being the case, in OnScreen, since no beams were present in the Kaiser building, concrete columns were accounted for on each floor, while each floor’s area was measured. The hollow structural steel (HSS) columns in the Kaiser building were modeled in the Extra Basic Materials, where their associated assumptions and calculations are documented.</td></tr>
<tr><td colspan="3">3.1 Concrete Column</td></tr>
<tr><td rowspan="2"></td><td>3.1.1 Column_Concrete_Beam_N/A_Basement</td><td>Because of the variability of bay and span sizes, they were calculated using the following calculation; the supported floor is the ground floor and area is 2679 m sqr

= sqrt[(Measured Supported Floor Area) / (Counted Number of Columns)]

= SQRT(2679/(2x71)

= 6.14m</td></tr>
<tr><td>3.1.2 Column_Concrete_Beam_N/A_GroundLevel</td><td>Because of the variability of bay and span sizes, they were calculated using the following calculation; The supported floor is the second floor and area is 2679 m sqr

= sqrt[(Measured Supported Floor Area) / (Counted Number of Columns)]

= SQRT(2679/94)

= 6.14m</td></tr>
</table>

		3.1.3 Column_Concrete_Beam_ N/A_Level2	**Because of the variability of bay and span sizes, they were calculated using the following calculation; The supported floor is third floor and the supported area is 1134** **= sqrt[(Measured Supported Floor Area) / (Counted Number of Columns)]** **= SQRT(1134/43)** **= 5.14m**
		3.1.4 Column_Concrete_Beam_ N/A_Level3	**Because of the variability of bay and span sizes, they were calculated using the following calculation; The supported floor is fourth floor and area is 2679 m sqr** **= sqrt[(Measured Supported Floor Area) / (Counted Number of Columns)]** **= SQRT(2679/69)** **= 6.23m**
		3.1.5 Column_Concrete_Beam_ N/A_Level4	**Because of the variability of bay and span sizes, they were calculated using the following calculation; The supported floor is fifth floor and the supported area is 1294** **= sqrt[(Measured Supported Floor Area) / (Counted Number of Columns)]** **= SQRT(1294/44)** **= 5.42 m**

4 Floors	**The Impact Estimator calculated the thickness of the material based on floor width, span, concrete strength, concrete flyash content and live load. The thickness is 130mm concrete with 0.15mm polyethylene on top of gravel. It is assumed to be 150mm thickness with 6 mil polyethylene for data input. Assumptions also had to be made for the concrete strength to be 30MPa, instead of the specified 25MPa. This was due to the IE's limitation to model only 20MPa, 30MPa, and 60MPa for concrete strengths.**		
5 Roof	**The live load was assumed to be 75 psf and the concrete strength was set to 4,000psi instead of the specified 3,500psi.**		
	5.1 Concrete Suspended Slab		
		5.1.1 Roof_ConcreteSuspended Slab	**The span size is adjusted to 9.75m for limits in Impact Estimator. The protection board was assumed to be Vapour Barrier and Polyethylene was assumed to be 6mil. The Gravel Ballast size is assumed to be 25.381mm since no specific size is availabe. R-20 Rigid insulation was assumed to be closest to Polyisocyanurate Foam. Live load is assumed to be 2.4kpa.**

		5.1.2 Roof_ConcreteSuspended Slab	**The span size is adjusted to 9.75m for limits in Impact Estimator. The protection board was assumed to be Vapour Barrier and Polyethylene was assumed to be 6mil. R-20 Rigid insulation was assumed to be closest to Polyisocyanurate Foam. Live load is assumed to be 2.4kpa.**
		5.1.4 Roof_ConcreteSuspended Slab	**The span size is adjusted to 9.75m for limits in Impact Estimator. Vapour Barrier was assumed to be Polyethylene 6mil. R-20 Rigid insulation was assumed to be closest to Polyisocyanurate Foam. Live load is assumed to be 2.4kpa.**
		5.1.4 Sloped glazing roof	**This type of roof was not counted towards to roof quantity since there is no close assumption in IMPact estimator and the area of the roof is less than 5% of the overall roof area.**

<table>
<tr><td rowspan="4">6
Extra
Basic
Materi
als</td><td colspan="3">The Hollow Structura Stell (HSS) columns were accounted for using count conditions for the different types. Using their cross sectional sizing, provided in the Steel Column Schedule in structural drawing 316-07-003, in conjunction with their height and per foot weight, referenced from the Steel Tube Institute, allowed for the calculation of the amount of HSS in weight for the columns seen below.</td></tr>
<tr><td colspan="3">6.1
Steel</td></tr>
<tr><td rowspan="2"></td><td colspan="2">6.1.1
XBM_Columns_HSS_(Tot
al Sum)</td></tr>
<tr><td></td><td>The following equation describes how the weight of Hollow Structural Steel was calculated;

All HSS is considered to be SC6 (HSS 203x152x8.0) since limited available informaiton. Total counts for SC6 is 133

All Hollow Structura lSteel columns were assumed to have a height of 10ft Long tons were used (ie. 1 Ton = 2000 lbs) in the conversion from lbs to Tons. The source that was cited for the weight of the HSS beams was The Steel Tube Institute at http://www.steeltubeinstitute.org/pdf/brochures/dimension_brochure.pdf.
The equation shows as the following:
Number of column x linear density x column height = 133 x 15. 62 x 10 / 2000
10.39 tons</td></tr>
</table>