Life Cycle Assessment of Frederic Lasserre Building at University of British Columbia

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University of British Columbia

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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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Abstract

The LCA analysis of Frederick Lasserre building was conducted using the OnScreen TakeOff Pro software to perform analysis on the structural drawing of the Frederick Lasserre building. The data collected from OnScreen TakeOff pro are then entered into the Impact Estimator (IE). The environmental impact of the data is then quantified through IE which uses the Athena LCI database and the TRACI impact assessment methodology.

Bill of Material (BoM), Summary Measures and Absolute Energy reports which were generated by IE were used in the environmental impact analysis of the Frederick Lasserre building. These reports were used to perform sensitivity analysis and building performance on the Frederick Lasserre building.

BoM report which is a list of the materials which were used in construction of the building and summary measure report data were used in sensitivity analysis. Through this analysis it was found that rebar has the highest environmental impact out of five other materials which were chosen from the Lasserre building for the purpose of sensitivity analysis.

The building performance analysis was done on the original Frederick Lasserre building and the upgraded Lasserre building. The upgraded Lasserre building surface areas where insulated so that the building meets the REAP standards. It was found that the energy payback period of the improved Lasserre building would be 4 months. From the analysis, it is recommended that further research be conducted into envelope performance upgrades.

Table of Contents

List of Tables

List of Figures

Abbreviation

BoM: Bill of Material

GWP: Global Warming potential

IE: Impact Estimator

LCA: life cycle analysis

LCI: Life Cycle Inventory

MJ: Mega Joules

REAP: Residential Environmental Assessment Program

SOG: Slab on Grade

TRACI: Tool for the Reduction and Assessment of Chemical and other environmental Impacts

USEPA: US Environmental Protection Agency

Introduction

Frederick Lasserre building is located at 6333 Memorial Road at UBC; the Frederic Lasserre Building is located near the intersection of Main Mall and Memorial Road, just north of the Koerner Library. Lasserre building has three entrances. The main entrance to this building is located on the east side of the building on Main Mall. This entrance is level and accessible and has a manual door. The second entrance is located at the west end of the building adjacent to Memorial Road. This entrance is level and accessible and has a power door which is the closest entrance to the elevator. The third entrance is located on the north side of the building in the Fine Arts Courtyard which is level and accessible and has a manual door.

The Frederick Lasserre building was opened at 1962 is used for Departments of Fine Arts, School of Regional and Community Planning, School of Architecture, and General University Facilities. Therefore, due to its main usage it’s appropriate to be named after Dr. Frederick Lasserre, first director of the UBC School of Architecture. Table 1 illustrates the characteristics of the Frederick Lasserre building features.

No information was found online regarding the total number of classrooms and occupancy of this building. However, the numbers of classrooms are 11 which include 2 lecture halls, 23 offices which are located at the fourth floor of the building and 4 design areas which are located on the second floor. There is no public access to the third floor of the building however, it is mainly used as design and working areas for students.

Table 1: Frederick Lasserre Building Feature Characteristics

Building Feature	**Characteristic**
Foundation	The foundation is concrete cast in place strip foundation with 6" vapour barrier.
Beam and Column	The beams and columns are made of concrete with 20(ft) bay size and 31.5(ft) span size for all floors including basement.
Exterior Wall	10" concrete blocks with 4" glazed brick on the exterior side of wall.
Interior Wall	Interior walls are assumed as concrete block the same as exterior walls with ½" gypsum board on both sides of the interior walls.
Window	Operatable single glazed with aluminum framing.
Roof	Flat concrete roof is modeled as concrete precast double T.
Floor	Floors are modeled as concrete precast double T.

Goal and Scope

Goal of Study

This life cycle analysis (LCA) of Frederick Lasserre building at the University of British Columbia was carried out as an exploratory study to determine the environmental impact of it's design. This LCA of the Frederick Lasserre 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 Frederick Lasserre building. An exemplary application of these references is in the assessment of potential future performance upgrades to the structure and envelope of the Frederick Lasserre 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 Frederick Lasserre 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 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.

Scope of study

The product systems being studied in this LCA are the structure and envelope of the Frederick Lasserre building on a square foot finished floor area of academic building basis. In order to focus on design related impacts, this LCA encompasses a cradle-to-gate scope that includes the raw material extraction, manufacturing of construction materials, and construction of the structure and envelope of the Frederick Lasserre building, as well as associated transportation effects throughout.

Tools, Methodology and Data

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

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

Using the formatted takeoff data, version 4.0.64 of the IE software, the only available software capable of meeting the requirements of this study, is used to generate a whole building LCA model for the Frederick Lasserre building in the Vancouver region as an Institutional building type. The IE software is designed to aid the building community in making more environmentally conscious material and design choices. The tool achieves this by applying a set of algorithms to the inputted takeoff data in order to complete the takeoff process and generate a bill of materials (BoM). This BoM then utilizes the Athena Life Cycle Inventory (LCI) Database, version 4.6, in order to generate a cradle-to-grave LCI profile for the building. In this study, LCI profile results focus on the manufacturing (inclusive of raw material extraction), transportation of construction materials to site and their installation as structure and envelope assemblies of the Frederick Lasserre building. As this study is a cradle-to-gate assessment, the expected service life of the Frederick Lasserre 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 Frederick Lasserre 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 Frederick Lasserre 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 generates a rough estimate of the energy payback period of investing in a better performing envelope.

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

Building Model

Take Offs

The on-Screen Takeoff pro is used to generate the Frederick Lasserre building‘s take offs. The take offs are mostly generated using the structural drawings except for the main floor which the drawings were not as clear, since they are handwritten Also, the drawings do not have special notes for the buildings feature characteristics, therefore some reasonable assumptions were made by considering the materials that were considering either the common at the time that Frederick Lasserre building was built or by walking through the building. For example, In order to generate takeoffs for the main floor reasonable assumptions were made based on my personal observations by walking through the Frederick Lasserre building.

For each of the building features a specific nomenclature was assigned which helps in entering the data in a more organized manner. The nomenclature format that is used for each of building’s features will be explained in the related section below.

Column and Beam

Both column and beam types are concrete in Frederick Lasserre building. The column and beams were modeled separately in the OnScreen TakeOff but modeled under one section in the IE. The nomenclature which is used for the column and beams in the IE is “Column _ column material _ a descriptor”.

In IE the method used to measure column sizing is dependent 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
- Live load

Table 2 illustrates the span and beam sizes for different floors. All floors except the fourth floor have the same bay and span size. In order to address two different span and bay sizes in fourth floor two conditions were generated under the column and beam section in IE.

Table 2: Span and Bay Sizes for Different Floors

Floor	Bay Size (ft)	Span Size (ft)
Main Floor	20	35.5
Second Floor	20	35.5
Third Floor	20	35.5
Fourth Floor	20	35.5
Fourth Floor	14	20

The assumptions were made for column and beam section in the IE is related to live load. The IE limits the live load options to 45, 75 and 100 (psi). The live loads for different building partitions are shown in the Table 3. For the roof the live load is assumed to be 45 (psi) as it is the closet to the specified 40 (psi), and for other floors and basement the applied live load 75 (psi) was assumed which is close to the average of the specified live loads for classroom, offices and corridor and stairs which is 70 (psi).

Table 3: Live Load According to Frederick Lasserre Building S8 Drawing

Building Partition	Live Load (psi)

Roof	40
Classroom	60
Offices	50
Corridors and stairs	100

The assumptions which were made about column and beam are covered in section 6 of Appendix B.

Roof

Roof has modeled as concrete precast double T in the IE. The nomenclature which is used for the roof is “Roof _ insert roof type _ a roof descriptor”.

A built up asphalt roofing system of fibreglass, glass felt and gypsum and a live load of 45 (psi) according to Table 3 are assumed for the roof. Section 4 and 4.1.1 in the Appendix B covers the assumptions which were made for roof.

Roof Area= (Bay Size *Number of Bays)* Span Size Equation 1: Roof Area

Floor

The floors were modeled as concrete precast double T. The nomenclature which is used for naming the floors in the IE is “Floor _ insert floor type_ a descriptor”. The span and bay size for all floors were the same except fourth floor which has divided to two sections due to different bay and span size. Since there were no note regarding the live load of the floors in the drawings, 75 (psi) was assumed as the applied live load for the floors. Appendix B section 3 covers roof assumptions.

In modeling the main floor, for simplicity it was assumed that the entire floor has the same elevation even though two lecture Halls beside the north side entrance of the building have different elevation. These two lecture halls area compare to the floor area is very small and also the elevation difference were small; therefore, in overall this assumption does not make a significant impact on the result.

Foundation

The three sections are assigned under the foundation section in the IE are slab on grade, footing and stairs.

1. Slab on Grade (SOG)

The floor slabs are modeled as SOG in the IE. The nomenclature which is used for SOG is “SOG _ (insert slab thickness)”. One of the limitations of the IE is that it only recognizes 4” and 8” slab thickness; therefore, the area of this slab had to be adjusted so that the thickness fit into the 4" thickness specified in the Impact Estimator. The calculations for SOG are shown in the Appendix B sections 1.1.1 to 1.1.6.

2. Footing

The Frederick Lasserre building only has strip footings. The nomenclature which is used for footings is “**Footing _** footing descriptor **_** location in building”. In The Impact Estimator there is a limitation range of [7.5", 19.7"] for acceptable thickness for concrete footing. In order to find the width corresponding to the corrected thickness the volume of original footing is calculated and equated to the volume of the corrected footing, to calculate the width related to the corrected volume. The calculations for Concrete Footings are shown in the Appendix B sections 1.2.1 to 1.2.3.

3. Stairs

The stairs are modeled under the footing as concrete footing and the used nomenclature is “Stairs _ information to help identify the stairs”.

The average thickness of the stairs has been used as the thickness, the width of the stairs is used as width and the length of the stairs is entered as the length of the concrete footing in the

IE. The assumption regarding the thickness of the stairs can be found in Appendix B section 1.2.4.

Wall

The nomenclature which is used for walls is “Wall _ insert wall type, ie. Cast-in-place and etc. _Wall name _ a descriptor that helps in identifying the wall”.

The Frederick Lasserre building walls are separated into different categories based on the used material, their thickness and envelope.

The wall categories due to used materials are:

- Cast in place
- Concrete Block

The cast in place walls show the strip foundation walls and the concrete blocks are used to model exterior and interior walls.

And the wall categories based on the wall thickness and different envelope are:

- Exterior walls
- Interior walls

Due to lack of information about the interior wall material, the interior walls material is assumed to be the same as exterior wall material only with different thickness. Also, due to my personal observation I added ½” gypsum board was assumed on both sides of the interior walls. In addition, the main floor drawing is so vague and I have created interior walls on the main floor drawing in the on screen based on my personal observations. The assumptions regarding the interior walls are sections 2.2.2 to 2.2.5 in Appendix B.

The thickness of some of the basement walls which were modeled as cast in place has changed in order to meet the IE requirements which are either 8” or 12”. For example a 10” cast in place wall thickness has been entered in the IE as 8”; consequently the length of the wall has been adjusted to a larger length to match the wall thickness change. The assumptions regarding the wall cast in place walls can be found in sections 2.1.1 to 2.1.4 in Appendix B.

Also for all of the basement walls a 6 (mm) vapour barrier has been assumed. This assumption was made based on 6” coating which is shown on the S1 Frederick Lasserre drawing and a vapour barrier layer which is shown on drawing number A-10; also considering the high moisture content of the soil in Vancouver considering a vapour barrier is a reasonable approach to avoid future problems with the foundation of a building.

Bill of Material (BoM)

After entering all the data from the On-Screen TakeOff to IE, IE software generates a report which shows the amount and the type of materials which are used in a building. Table 4 shows the BoM for Frederick Lasserre building in both SI and Imperial units.

In Table X below, the five materials which are used in large amounts in the Lasserre building have been highlighted with orange color. These materials are:

- Gypsum Board
- Aluminum
- Concrete Block
- Rebar, Rod Light Sections
- Roofing Asphalt

½" Fibreglass gypsum board has been used on both sides of the interior walls of the Lasserre building. The amount of gypsum board that is used in the Lasserre building is 133960.6 (SF). No information regarding the wall coatings was found in the structural drawings of the Lasserre building. The assumption that both sides of the interior walls are coated with gypsum boards is made by personal observation.

The window frames of Lasserre building is made out of aluminum. Since the exterior walls have a lot of windows the amount of aluminum used in this building to be 8.8 (Tonnes). No assumption was made regarding the material of the window frames, but the structural drawings of Lasserre building only offers the window drawings for one side of the building therefore A-7 drawing was duplicated to simplify the window area and count procedure in the OnScreen TakeOffs.

Frederick Lasserre building's structure is mainly concrete which is assumed to have a 3000 (psi) with average amount of fly ash in its mix design. This assumption was made based on the fact that in some of the Lasserre drawings the type of concrete is mentioned as light weight concrete. In general the compressive strength of lightweight concrete after 28 days of curing is approximately 3000 (psi).

As illustrated in Table 4 below, the amount of concrete blocks which is used for Lasserre building's exterior and interior walls is 52240.1681 (Blocks). Also large amount of concrete usage in Lasserre building has lead into large amount of rebar in the building. The rebar used in the Lasserre building is 353.1 (Tonnes).Rebar is used to improve the concrete performance in tension. Number 4 rebar was used in the foundation of the Lasserre building. Only one type of rebar was specified in the Lasserre building's drawings, therefore no assumptions were made regarding the rebar number.

The Lasserre building roof was modeled as concrete precast double T with a built up asphalt roof system envelope. The roof envelope was assumed based on the common type of the roof when the Lasserre building was built. The amount of asphalt used for the roof of Lasserre building is 31306.7 (lbs).

Table 4: BoM Report from IE

	SI		Imperial	
Material	Quantity	Unit	Quantity	Unit
#15 Organic Felt	2406.3218	m2	259.0165	100sf
1/2" Gypsum Fibre Gypsum Board	12445.3507	m2	133960.635	Sf
1/2" Moisture Resistant Gypsum Board	1160.9164	m2	12495.9995	Sf
3 mil Polyethylene	699.5189	m2	7529.5581	Sf
6 mil Polyethylene	170.565	m2	1835.9468	Sf
Aluminum	7.9839	Tonnes	8.8022	Tons
Ballast (aggregate stone)	22162.9492	kg	48860.9392	Lbs
Batt. Fiberglass	6611.4129	m2 (25mm)	71164.6539	sf(1")
Cold Rolled Sheet	0.3915	Tonnes	0.4316	Tons
Concrete 20 MPa (flyash av)	943.0546	m3	1233.4688	yd^3
Concrete 30 MPa (flyash av)	1395.0065	m3	1824.5997	yd^3
Concrete 60 MPa (flyash av)	1048.7814	m3	1371.7543	yd^3
Concrete Blocks	52240.1681	Blocks	52240.1681	Blocks
Concrete Brick	2035.0439	m2	21905.029	Sf
EPDM membrane	308.1563	kg	679.3684	Lbs
Galvanized Sheet	1.2575	Tonnes	1.3865	Tons
Glazing Panel	0.2028	Tonnes	0.2236	Tons
Joint Compound	12.4207	Tonnes	13.6938	Tons
Mortar	204.2085	m3	267.0947	yd^3
Nails	1.179	Tonnes	1.2998	Tons
Paper Tape	0.1426	Tonnes	0.1572	Tons
Rebar, Rod, Light Sections	320.3076	Tonnes	353.139	Tons
Roofing Asphalt	14200.4647	kg	31306.6657	Lbs
Small Dimension Softwood Lumber, kiln-dried	7.141	m3	4.3703	Mbfm
Standard Glazing	302.9838	m2	3261.29	sf
Type III Glass Felt	4812.6436	m2	518.033	100sf
Water Based Latex Paint	60.9466	L	16.1022	US Gallon
Welded Wire Mesh / Ladder Wire	16.9762	Tonnes	18.7162	Tons

Summary Measures

For the Lasserre building the report of summary measures was taken from IE. The summary measure table by life cycle stage covers the bellow listed factors, during manufacturing, construction, maintenance, and end-of-life stages; however, for the purpose of this report only manufacturing and construction stages will be addressed assuming up to when construction is completed on the building.

1. Primary Energy Consumption
2. Weighted Resource Use
3. Global Warming Potential
4. Acidification Potential
5. HH Respiratory Effects Potential
6. Eutrophication Potential
7. Ozone Depletion Potential
8. Smog Potential

Figure1 below illustrates some of the environmental impact categories listed above.

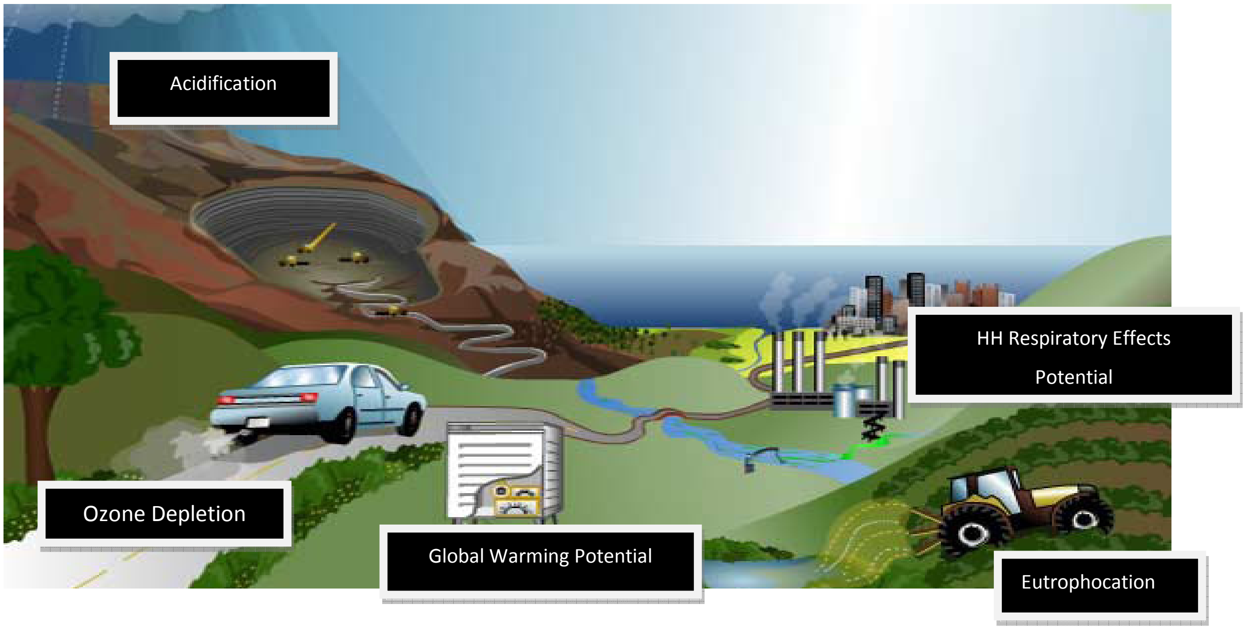

Figure 1: Environmental Impact Categories (OSRAM Opto Semiconductors GmbH, 2009)

The primary energy consumption defines the required energy for different stages of life cycle.

Weighted resource depends on the amount of resource and its weighted factor. The weighted resource factor is calculated by multiplying each material by its weight and then summing all the weighted materials to get the weighted value. The weight factors are assigned to each material based on the expert opinions about the ecological impact of the material's extraction." The weight resource is represented by natural gas, hard coal, lignite, and crude oil. It is formed by the amount of resources that is depleted" (OSRAM Opto Semiconductors GmbH, 2009).

Global Warming potential (GWP) is the measure of how much a given mass of a material will contribute in the global warming.
Greenhouse gases have the ability of capturing heat in the atmosphere. Although CO_2 does not have the greatest contribution in the global warming, among all of greenhouse gases LCA uses the CO_2 emission to illustrate a material's GWP, by converting the greenhouse gas emissions to their CO_2 equivalence (Global Warming Potential, 2009). GWP expresses the cumulative radiative forcing value caused by an emission of a unit mass of a given greenhouse gas (GHG) over a defined time horizon, relative to the equivalent value for CO_2. Hence, to determine the life cycle impact score for the global warming impact category in "kg CO_2 equivalent", the LCI results for each greenhouse gas are multiplied by their respective GWP ". A very important factor in finding GWP is the chemical lifetime, since the mathematical formula which is used by LCA to calculate a material GWP is directly related to the lifetime of the emission. (Annie Levasseur, Pascal Lesage, Manuele Margni, Louise Deschnes and Rjean Samson, 2010).

The acidification occurs by replacement of nutrient bases with acid elements due to pollutants in the air. This transformation causes the rain water PH and fog PH to decrease. Acidification damages ecosystems and could have impact on human health especially if the pollution is in the forms of NO_x or SO_2 because they can cause acidic rains by forming H_2SO_4 and HNO_3 (Keulenaer, 2006).

The eutrophication is an increase in the concentration of chemical nutrients which leads to abnormal activity in the ecosystem. “Eutrophication originates mainly from nitrogen and phosphorus in sewage outlets and fertilizers. Thus the EP is caused mainly by nitrogen oxide (NOx) emissions, followed by chemical oxygen demand and ammonia” (Dr.Hall Civl 405 Notes, 2009).

The ozone depletion potential of a material is a relative amount of degradation to the ozone layer an emission can cause (Wikipedia). Smog is ground-level ozone which is formed from when vehicle emissions containing nitrogen oxides (primarily from vehicle exhaust) and volatile organic compounds (from paints, solvents, and fuel evaporation) interact in the presence of sunlight (what is smog-, 2010). Smog potential indicates an equivalent mass of ethylene.

Sources of Uncertainty

The uncertainties related to the Frederick Lasserre building is mostly due to data quality, temporal, special, building life span and operation.

Different emissions lasting period which is the periods that they can have negative effect on ecosystem is different which this LCA does not account for it. This leads to temporal uncertainty.

This LCA does not account for different locations that emissions occur which cause the spatial uncertainty. For example, the emissions related to manufacturing a material has occurred in different location than the emissions which occurred during transportation. Also, this LCA does not either separate different types of emissions or the interaction which different emissions could have with each other. This is also another source of uncertainty, as the impact of each emission could differ from another type of emission.

Sensitivity Analysis

Sensitivity analysis is used to determine the impact of a material on the outcome if its value has changed from its original value. Sensitivity analysis can help in decision makings which are necessary in the design phase for a building. During this stage the type of materials are chosen for a building. A sensitivity analysis report on different materials could help in making decisions which are both more environmentally friendly and more economical.

The sensitivity method used in Lasserre building changed one parameter amount by increasing it by amount E, Equation 2, and creating a new summary measure table report. The calculated E is added to the original amount of a specific material in a building, so that the impact of change in the amount of that material could be analysed on the overall environmental impact of the building. The sensitivity analysis can be done by comparing the new report to the original report. Using this method allows the impact of change in the amount of one specific material to be evaluated.

$$E = \frac{(Original\ amount\ * 10\%)}{(1 + Assigned\ Waste\ Factor)}$$

Equation 2

Table 5 shows the top five materials according to their required amount in the building and their assigned waste factor for the sensitivity analysis. By analyzing sensitivity data it was noticed that the manufacturing process of a material has significant impact on overall building environmental impact.

Table 5: Chosen Materials for Sensitivity Analysis

Materials	Amount	Waste Factor
1/2" Gypsum Fibre Gypsum Board	12445.350 (m^2)	10%
Aluminum	7.98 (Tonnes)	0%
Concrete Blocks	52240.168 (Blocks)	5%
Rebar, Rod, Light Sections	320.31 (Tonnes)	1%

Cold Rolled Sheet	0.3915 (Tonnes)	1%

½” Fibreglass Gypsum Board

A sensitivity analysis is done on the amount of gypsum board used in the Lasserre building. Figure 2 illustrates the impact of adding 1131.40(m^2) to the amount of ½” fibreglass gypsum board material which is used in the original construction o f the Lasserre building.

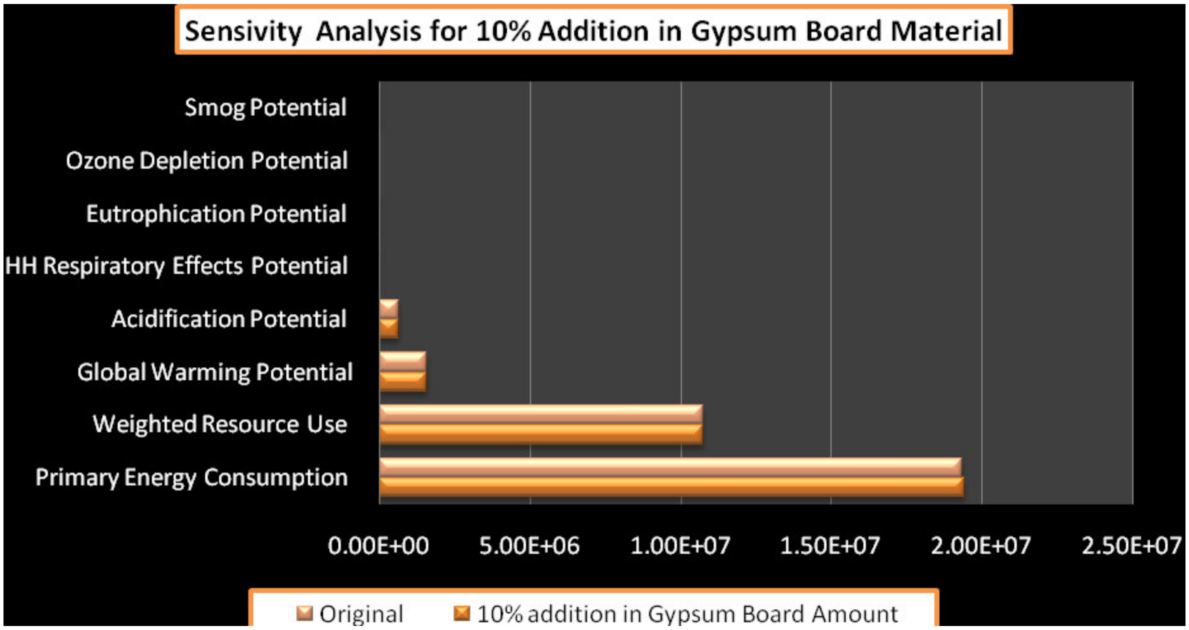

Figure 2: Sensivity Analysis for 10% Addition in Gypsum Board Material

Figure 3 shows the percentage difference of the impact of 10% addition to the amount of gypsum board amount considering waste factor compare to the original amount of this material in the Lasserre building. Figure 2 shows that the most impact of that this extra gypsum board material has on overall environmental impact of the building are increasing the primary energy consumption by 0.56% compare to the original building. The second affect that gypsum board has is on HH respiratory effect potential by 0.37%.The addition in amount of gypsum board also has increased overall environmental impact of Lasserre building on global warming and acidification by 0.36%. These environmental impact differences are insignificant and can be neglected. Therefore, addition of the gypsum board does not drastically change the overall environmental impacts of the Frederick Lasserre building.

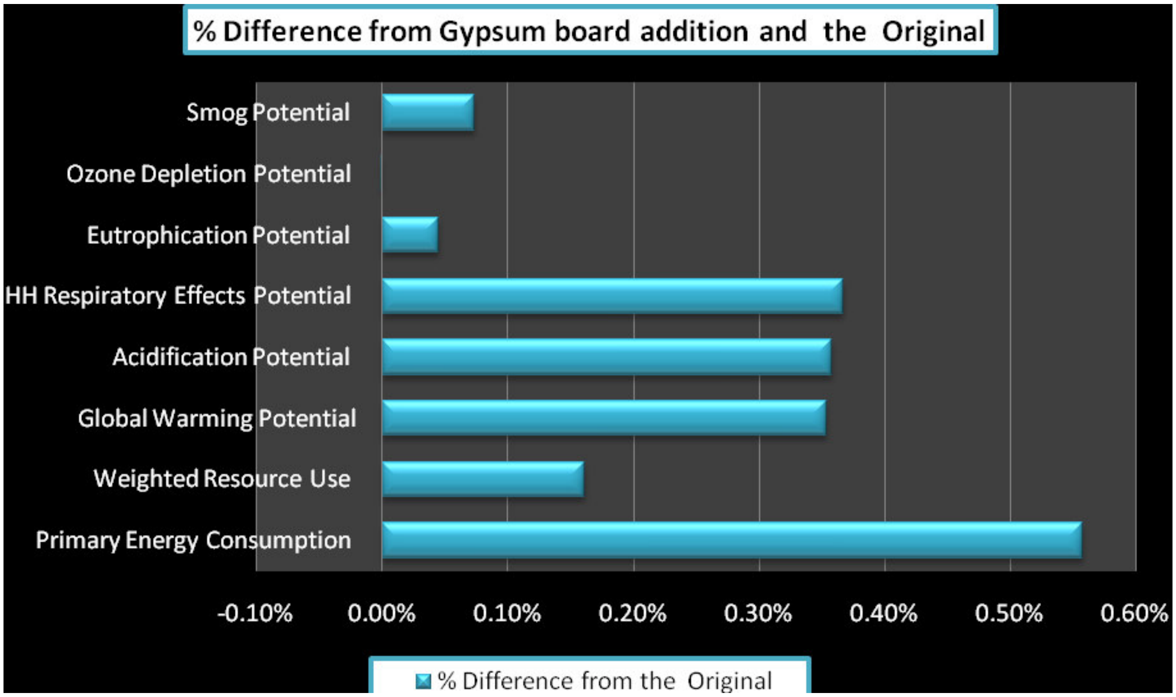

Figure 3: % Difference between the Extra Gypsum and the Original

Aluminum

Figure 4 shows the impact of 10% additional in the Aluminum amount vs. the original amount of aluminum which was consumed in the Lasserre building construction. The additional amount of aluminum which was calculated considering its waste factor is 0.8 (Tonnes).The main usage of aluminum in the Frederick Lasserre building is for window frames. Aluminum was chosen based on the fact that it is considered as a toxic material for fresh water and aquatic life.

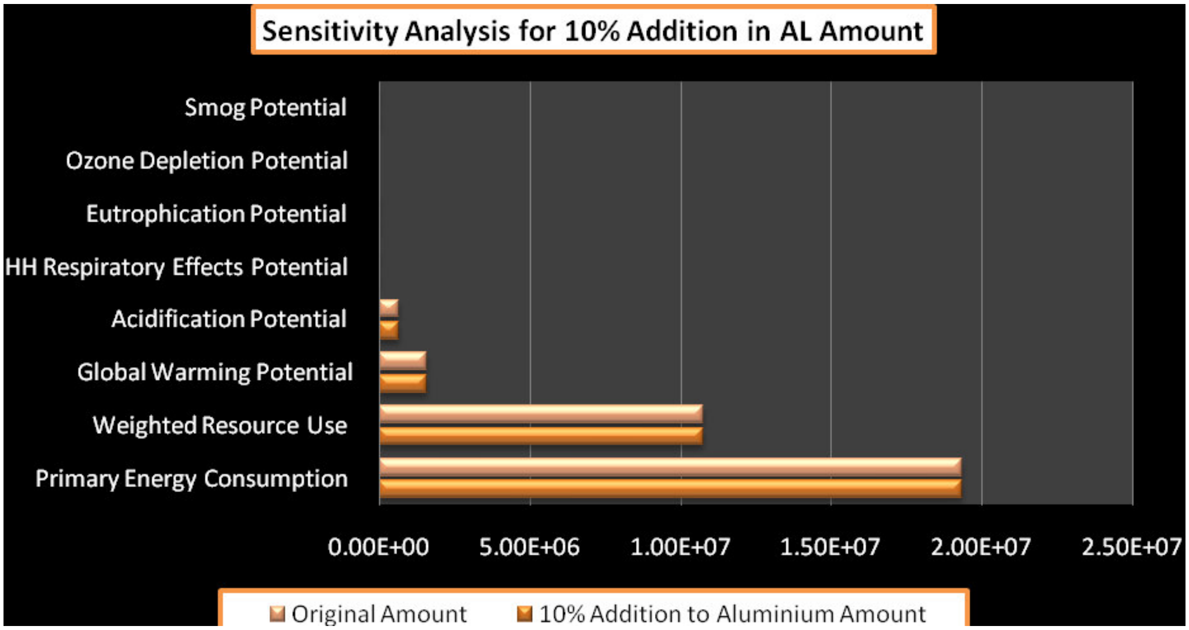

Figure 4:10% Addition in Al Amount vs. Original Amount

Figure 5 illustrates the percentage difference that 0.8 (tonnes) of aluminum has on the environmental impact of the Lasserre building. The highest impact of aluminum is on the human health respiratory effect which is 0.34 % and the second largest impact is eutrophication effect which is 0.30 %. The other two environmental impact factors that this increase in amount of aluminum has is to increase the overall impact of Lasserre building's smog and energy consumption potential by 28% and 19%. From Figure 5 it is reasonable to assume that the additional of aluminum will not significantly affect the environmental impact of the Lasserre buildings.

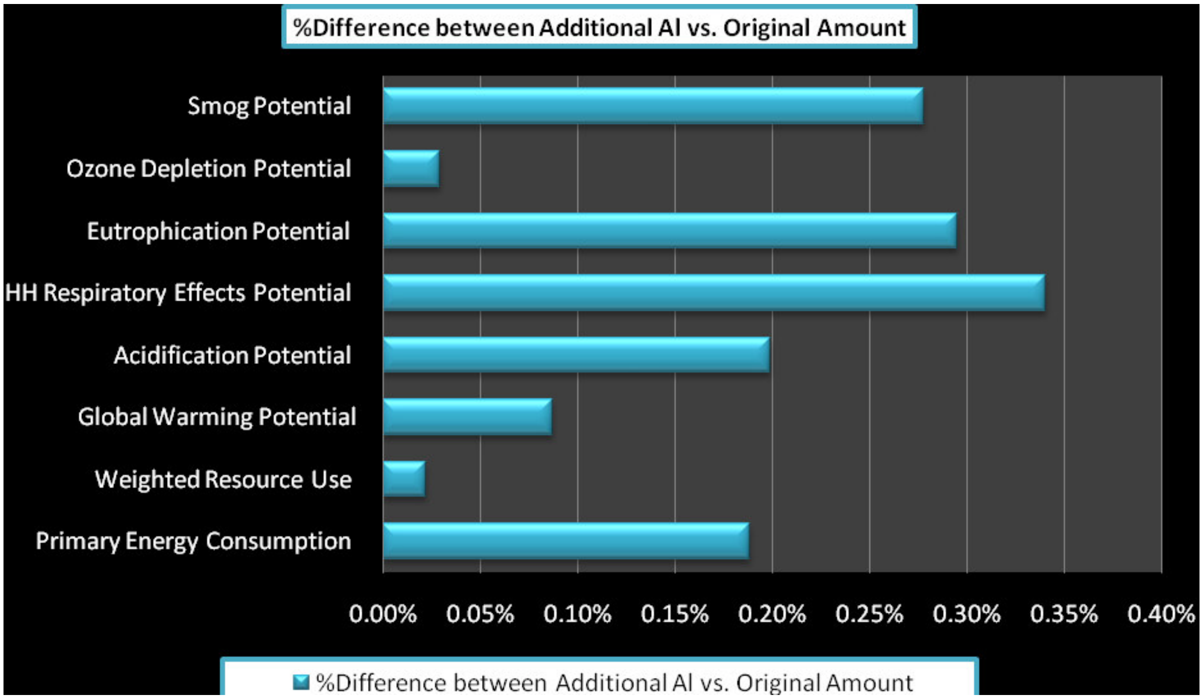

Figure 5: % Difference between Additional Al vs. Original Amount

Concrete Block

The Frederick Lasserre structure is mainly made out of concrete which concrete blocks account for most of the concrete which is used in this building. The 10% addition to the amount of concrete blocks considering the waste factor for the concrete blocks is 4975.25 (Blocks). Figure 6 compares the environmental impact of the 10% addition to the amount of concrete blocks of Lasserre building with its original amount of concrete blocks.

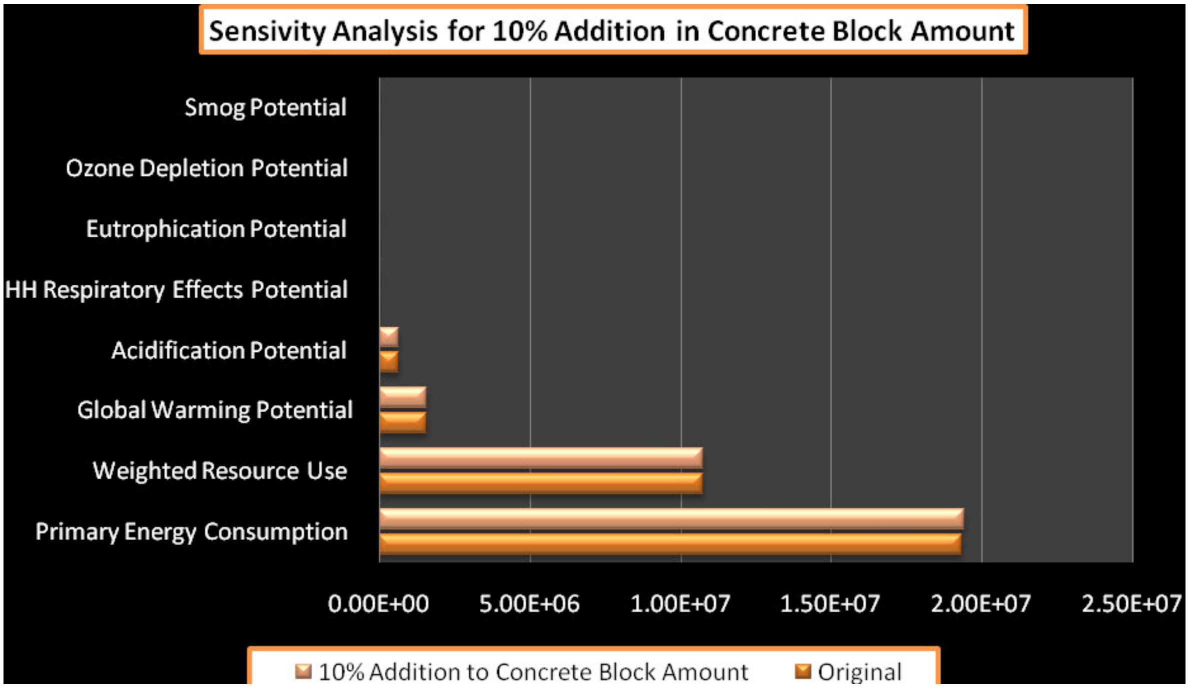

Figure 6: 10% Addition in Concrete Block Amount vs. Original Amount

Figure 7 illustrates the percentage difference that 4975.25 (Blocks) of concrete block has on the environmental impact of the Lasserre building compare to the building with the original amount of concrete blocks. The highest impact of concrete block is related to the acidification which is 0.75 % and the second highest impact is related to global warming, ozone depletion and HH respiratory potential which increases the overall environmental impact by 0.70%. One reason that the additional amount of concrete block does not increase the environmental impacts of the Lasserre building as expected could be due to the fact that this LCA model does not differ between the emission locations, most emission regarding the concrete comes from cement which its production highly contributes to CO_2 emission and smog potential. Concrete Blocks are usually built off the site and are shipped to construction sites. These concrete ready mix plants are mostly located on the suburbs of cities. Although the percentage difference values for addition of concrete blocks are not significantly different from the original amount of concrete blocks in the building, addition of concrete blocks amount have negatively affected the entire environmental impact category except weighted resource use. Therefore, it is advisable to reduce the amount of concrete in buildings.

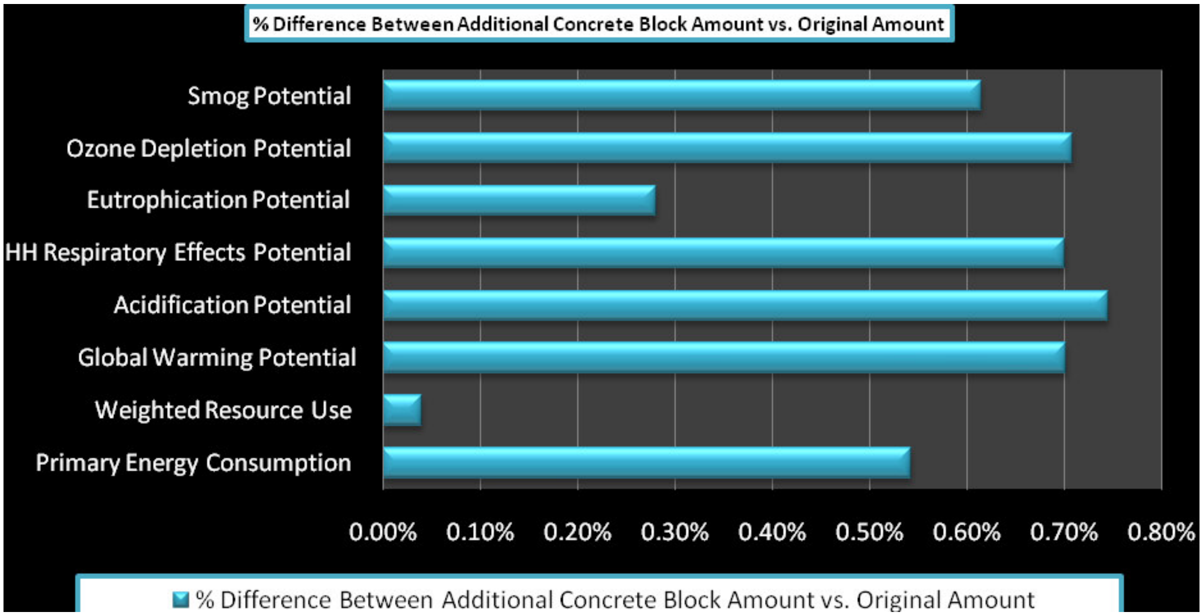

Figure 7: % Difference between Additional Concrete Block Amount vs. Original Amount

Rebar Light Sections

The additional amount which was used to conduct sensitivity analysis for rebar is 31.71(Tonnes).The high amount of rebar in the Frederick Lasserre building is due to high amount of reinforced concrete which is used in the Lasserre building. Out of all the five materials which were chosen for the sensitivity analysis; rebar has the most affect on the environmental impact factors. Figure 8 compares the environmental impact of the 10% addition to the amount of rebar of Lasserre building with the original amount of rebar in the structure of Lasserre building.

Considering the large amount of fossil fuels which is required for producing steel this significant environmental impact was expected. “Integrated steel mills use a three-step process to produce steel from coal, involving cokemaking, ironmaking (using a blast furnace), and Basic Oxygen Furnace (BOF) technology. Coke, which is the fuel and carbon source at integrated mills, is produced by heating coal in the absence of oxygen at high temperatures in coke ovens. Pig iron is then produced by heating the coke, iron ore, and limestone in a blast furnace. In a BOF, molten iron from the blast furnace is combined with flux and scrap steel where high-purity oxygen is injected. This process—with cokemaking, ironmaking, steelmaking, and subsequent forming and finishing operations—is referred to as “fully integrated production”” (Tyler, 2009).

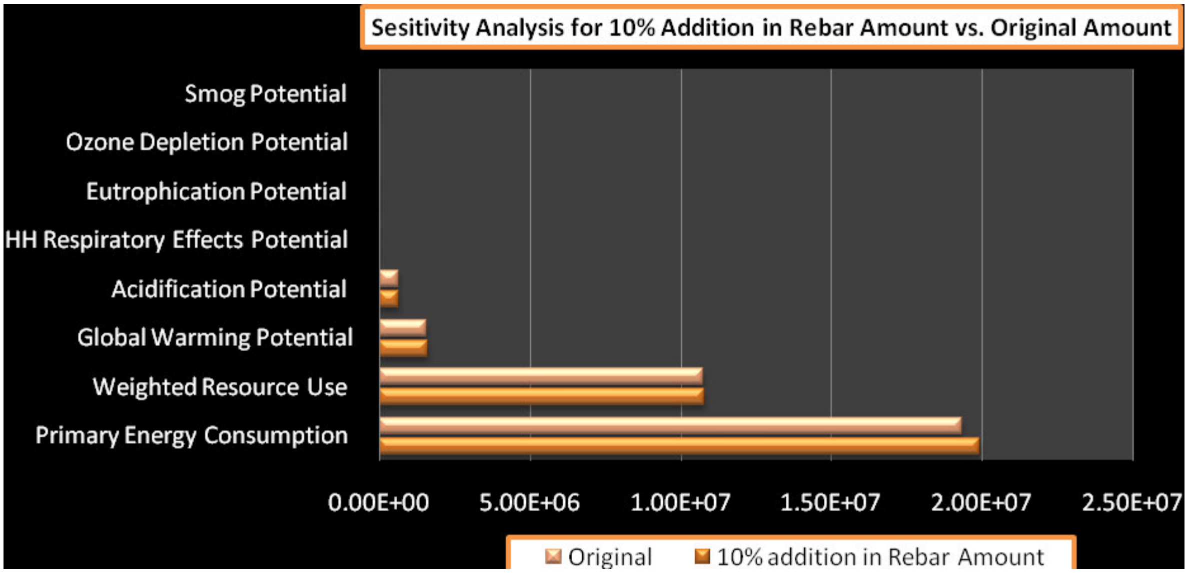

Figure 8 :10% Addition in Rebar Amount vs. Original Amount

The addition of rebar has caused the eutrophication potential to increase by 5.2% and the primary energy consumption by 3.18%. This change in the amount of rebar has also caused an additional 1.30% and 1.07% impact of the Lasserre building on the global warming and acidification potential. These percentage differences are shown in Figure 9.

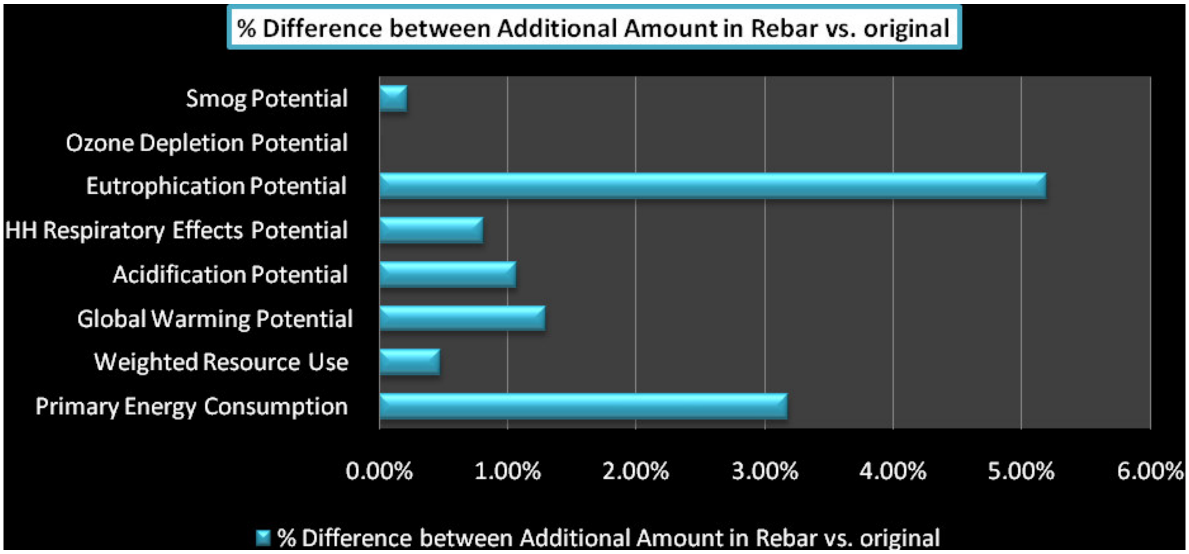

Figure 9 : % Difference between Additional Rebar Amount vs. Original Amount

Cold Rolled Sheet

The additional amount which is used to run sensitivity analysis for cold rolled sheet is 0.04(Tonnes). Cold rolled sheet was chosen to show the important role of material quantity on environmental impact factors of a building. Cold rolled sheet production process is almost the same as steel production; however, since the original amount and consequently the additional amounts were insignificant compare to the total building material the impact of adding extra cold rolled sheets to the Lasserre building materials is almost insignificant, as it is shown in Figure 10.

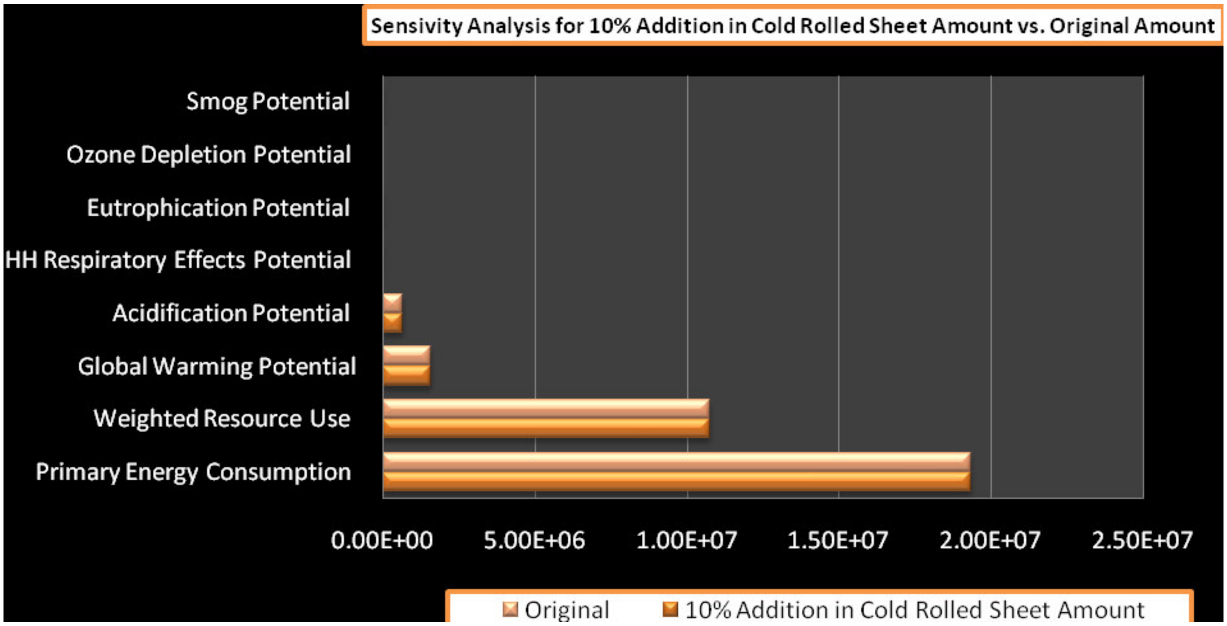

Figure 10: 10% Addition in Cold Rolled Sheet Amount vs. Original Amount

The addition of rebar to the original IE summary measures report has caused the maximum of 0.0061% in primary energy consumption, as shown in Figure 11.This percentage difference can be assumed as no difference from the original building overall environmental impacts .

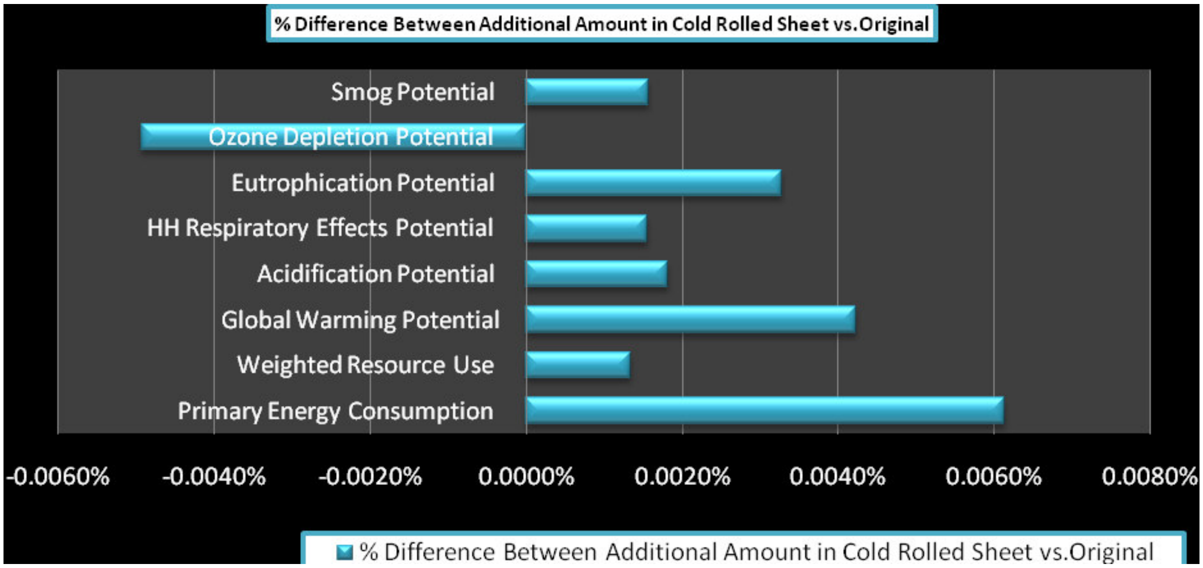

Figure 11: % Difference between Additional Cold Rolled Sheet vs. Original Amount

Building Performance

Building performance is a set of measurable building characteristics which is used to fix and improve the comfort and energy efficiency of a building. Building performance can address the following issues:

- Durability
- Moisture Management
- Energy Efficiency
- Indoor air quality
- Thermal Comfort (Building performance, 2010)

A building performance analysis has been conducted on the Frederick Lasserre building by improving the R-value, which is a thermal resistance factor, of the Lasserre's building surface. The high R-value indicates the building insulation effectiveness is high.

Hence, for the purpose of Lasserre building's building performance analysis a set of insulations were added to the current building exterior walls and its roof. Furthermore, the window glazings were changed to a Low E silver argon filled glazing. These insulation upgrades on the Lasserre building has improved the R –values of exterior walls, windows and the roof. This change is shown in the Table 6.

The amount of heat which is transferred through the building surface by conduction is then calculated using Equation 3 which gives the heat loss in BTU for the month. The conversion factors are used to convert BTU into kWh and J.

$$Q = \left(\frac{1}{R} * A * \Delta T\right) * (\text{Number of hours in a month}) \qquad \text{Equation 3}$$

Where,

- R = Calculated R-Value in ft^2 ºF h/BTU (these are the Imperial units)
- A = Assembly of interest ft^2
- ΔT = Inside Temperature – Outside Temperature in ºF
- Inside temperature was assumed 68°F(20°C)

Also,

- 1 BTU = 0.00029307108333 kWh
- 1 BTU = 1055.0559 J

Table 6: Current and Improved Lasserre Building R-Values

		R-Value (ft2.degF.h/BTU)	
Building Feature	Area(ft^2)	Current R-Value	Improved R-value
Exterior Wall	21685	4.25	18
Window	9064	0.91	3.75
Roof	11360	3.44	40

Frederick Lasserre building was built 48 years ago; therefore, improving the R-values has allowed the Lasserre building to meet the current insulation standards for the Residential Environmental Assessment Program(REAP).

Table7 tabulates the type and thickness of added insulations to the exterior walls, roof and windows in order to convert the current building to a more energy efficient improved building.

Table 7: Improved Building insulation Features

Building Feature	**Added Insulation Type**	**Thickness**	**R-Value** (R-Value Table, 2008)
Exterior Walls	Polyisocyanurate Foam	1.94(in)	7.2
Windows	Low E silver argon filled glazing (3mm glass with 1/2" airspace)	3.75	3.75
Roof	Polyisocyanurate Foam	5.1(in)	7.2

Polyisocyanurate foam boards were chosen to improve the exterior wall and roof energy efficiency. This decision is made due to highly desirable features of the Polyisocyanurate foam boards, such as:

- <u>Noncorrosive</u>: the Polyisocyanurate foam does not accelerate corrosion of pipes, wiring or metal studs.
- <u>Lightweight</u>: easy to handle, can be cut with a utility knife or saw.
- <u>Thermal Efficiency</u>: polyisocyanurate foam provides the highest degree of insulation efficiency available, resisting heat transfer with R-values up to R-22.8 (RSI-4.01). It reduces thermal bridging at the framing members where fiber glass batts don’t insulate; therefore, improving the overall thermal efficiency of walls (Building Insulation /Rigid Foam Board, 2010).

To improve the energy efficiency of the windows two options were provided in the lecture which the option that provides higher R-value was chosen.

Figure 12 shows the energy loss graph for both current and improved buildings.

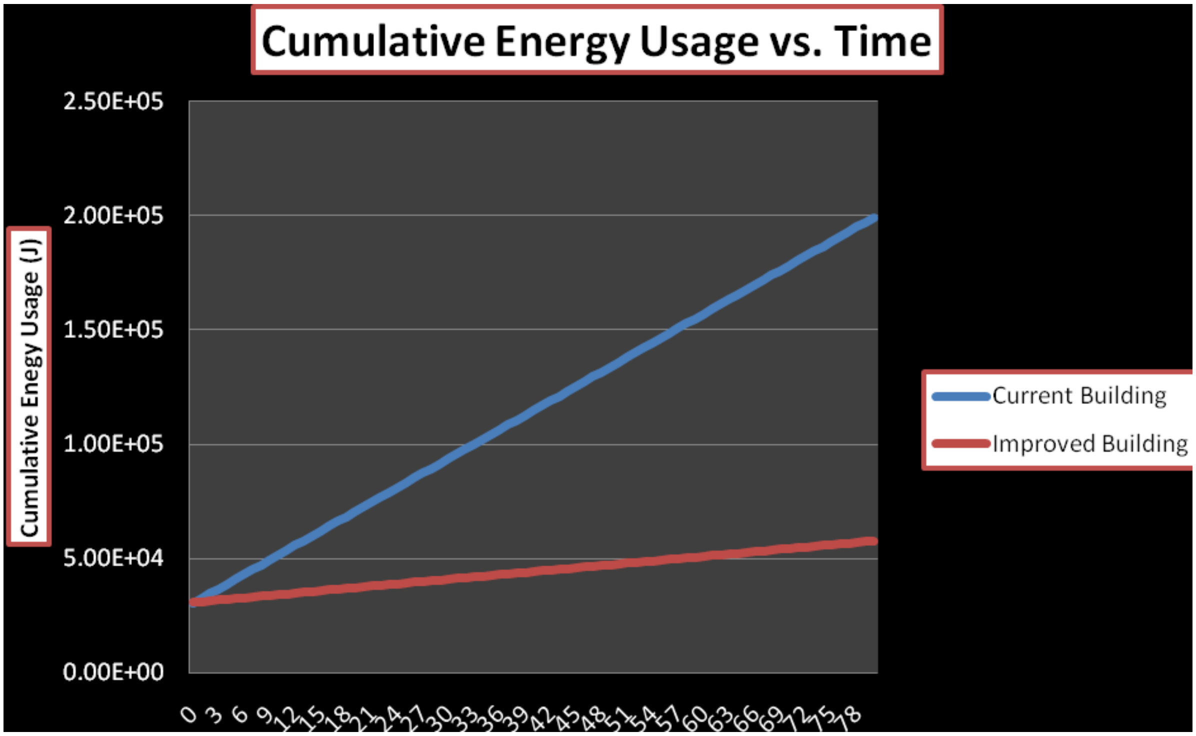

Figure 12: Cumulative Energy Usage vs. Time

In order to show the intersection of current and improved energy loss lines only the first three years the cumulative energy usage vs. time graph has been re-graphed. The improved and current energy loss line intercept point is important as it represents the energy payback period. From Figure 13 the energy payback period can be estimated approximately 4 months. This means that it takes 4 months to save the energy that was invested into reducing the building's heat loss.

Also, the IE energy reports for both current and improved building illustrates that the current building energy consumption is 30344222 (MJ) and the improved building energy consumption is 30858026 (MJ). The improved building energy consumption value is higher than the current building, this positive difference between current and the improved building energy consumption is because of the extra insulation materials which were added to the building envelope in IE to upgrade the buildings to REAP standards. As Figure 13 shows, after the current and improved building energy consumption lines intersect at the energy payback period point;

the energy consumption of the improved building will remain lower than the current building for the rest of its service life.

Figure 13 also justifies additional cost of building an energy efficient building by considering appropriate layers of insulation on a building's surface, as the payback time is less than a year and in the long term more money can be saved.

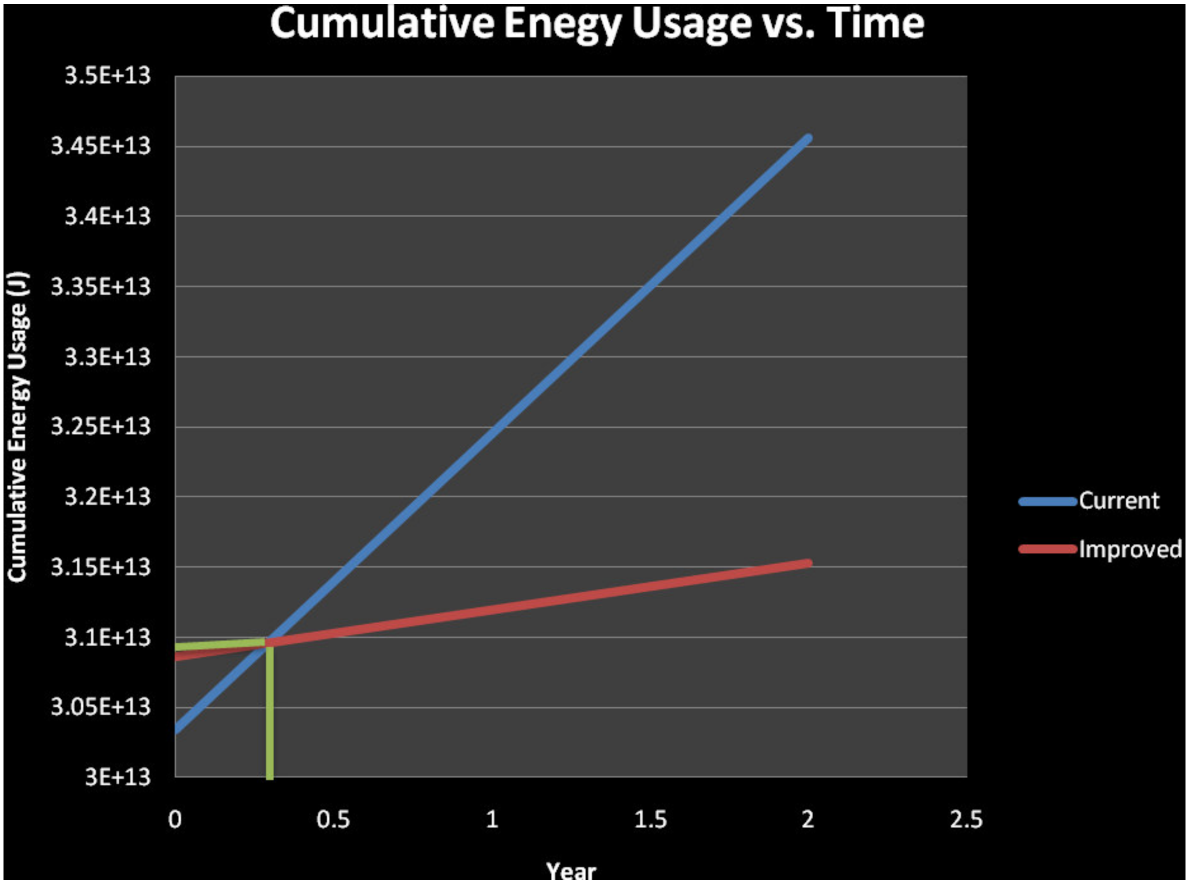

Figure 13: Energy Payback Period of the Current and Improved Building

Conclusion

The required data for conducting a LCA analysis using IE software were obtained from OnScreen TakeOff Pro software.

To conduct LCA on the Frederick Lasserre building the summary measure, BoM and absolute value energy reports were taken from the IE.

The summary measures by life cycle stage show the overall environmental impact of the Frederick Lasserre building. Summary measure report divides the overall life cycle of the Lasserre building into manufacturing, construction, maintenance, end-of- life and operation energy stages. Each of these life cycle stages environmental impacts were the divided to material and transportation. By comparing the manufacturing stage values to other life cycle stages impact it was concluded that the manufacturing stage has the most impact on overall building environmental impact.

The BoM report was used for undertaking sensitivity analysis on the Frederick Lasserre building. BoM shows the list and amount of materials used in a building in both SI and imperial units. The top five prevalent materials from the BoM list were chosen and sensitivity analyses were conducted on them to determine the impact of each of those materials on overall environmental impact of the Lasserre building. Rebar rod light sections showed the most negative overall environmental impact by increasing eutrophication potential by 5.2%, the primary energy consumption by 3.18% , the global warming impact by 1.30% and the acidification potential by 1.07%.This is due to rebar manufacturing process which is highly requires fossil fuel.

The absolute value energy report was used to conduct a building performance on the Frederick Lasserre building. An improved version of the Frederick Lasserre building which meets the REAP standards was created by adding insulation to the surface of the Lasserre building. The improved building energy consumption was then compared with the current Lasserre building.

The results of the building performance justify the initial high cost of designing a building energy sufficient by showing a payback period of 4 months which is an insignificant period of time considering the service life of a building.

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Appendix A: Impact Estimator Input Table

IE Inputs Document - Lasserre

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_ Roof_Plan Area			
			Length (ft)	160.00	160.00
			Width (ft)	71.00	71.00
			Thickness (in)	4	4
			Concrete (psi)	3000	3000
			Concrete flyash %	average	average
		1.1.2 SOG_Main Floor _Plan Area			
			Length (ft)	160.00	160.00
			Width (ft)	71.00	71.00
			Thickness (in)	4	4
			Concrete (psi)	3000	3000
			Concrete flyash %	average	average
		1.1.3 SOG_Second Floor_ Plan Area			
			Length (ft)	160.00	160.00
			Width (ft)	71.00	71.00
			Thickness (in)	4	4
			Concrete (psi)	3000	3000
			Concrete flyash %	average	average
		1.1.3 SOG_ThirdFloor_ Plan Area			
			Length (ft)	160.00	160.00
			Width (ft)	71.00	71.00
			Thickness (in)	4	4
			Concrete (psi)	3000	3000
			Concrete flyash %	average	average
		1.1.3 SOG_Fourth Floor_ Plan Area			
			Length (ft)	160.00	160.00
			Width (ft)	71.00	71.00
			Thickness (in)	4	4
			Concrete (psi)	3000	3000
			Concrete flyash %	average	average
	1.2 Concrete Footing				
		1.2.1 Footing_			

		Strip_Basement_F A_A			
			Length (ft)	59	59
			Width (ft)	1.60	1.60
			Thickness (in)	10	10
			Concrete (psi)	-	3000
			Concrete flyash %	-	average
			Rebar	#4	#4
		1.2.2 Footing_Strip_Basement_F C_C			
			Length (ft)	345	345
			Width (ft)	2.20	2.20
			Thickness (in)	12	12
			Concrete (psi)	-	3000
			Concrete flyash %	-	average
			Rebar	#4	#4
		1.2.3. Footing_Strip_Basement_F E_E			
			Length (ft)	88	88
			Width (ft)	2	2
			Thickness (in)	12	12
			Concrete (psi)	-	3000
			Concrete flyash %	-	average
			Rebar	#4	#4
		1.2.4 Footing_Strip_Basement_F H_H			
			Length (ft)		27
			Width (ft)	2.6	1.6
			Thickness (in)	19	19
			Concrete (psi)	-	3000
			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.5 Footing_Strip_Basement_F M_M			
			Length (ft)	64	64
			Width (ft)	2.2	2.78
			Thickness (in)	19	19
			Concrete (psi)	-	3000
			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.6 Footing_Strip_Basement_F P_P			
			Length (ft)	123	123
			Width (ft)	2.00	2.00
			Thickness (in)	12	12
			Concrete (psi)	-	3000
			Concrete flyash %	-	average
			Rebar	#5	#5

		1.2.7 Footing_Strip_Basement_FR_R			
			Length (ft)	66	66
			Width (ft)	2	2
			Thickness (in)	12	12
			Concrete (psi)	-	3000
			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.8 Footing_Strip_Basement_FS_S			
			Length (ft)	47	47
			Width (ft)	1.60	1.60
			Thickness (in)	8	8
			Concrete (psi)	-	3000
			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.9 Footing_Stairs_ Main Floor			
			Length (ft)	187	187
			Width (ft)	5.60	5.60
			Thickness (in)	10.5	10.5
			Concrete (psi)	-	3000
			Concrete flyash %	-	average
			Rebar	#4	#4
Wall	2.1 Cast In Place				
		2.1.1 Wall_Cast in Place _Strip Footing_ Basement_ A_A			
			Length (ft)	62	62.00
			Height (ft)	13.6	13.6
			Thickness (in)	8	8
			Concrete (psi)	-	3000
			Concrete flyash %	-	average
			Rebar		
		2.1.2 Wall_Cast in Place _Strip Footing_ Basement_ C_C			
			Length (ft)	362	452.5
			Height (ft)	13.6	13.6
			Thickness (in)	10	8
			Concrete (psi)	-	3000
			Concrete flyash %	-	average
			Rebar		#5
		Envelope	Category	-	Vapour Barrier
			Material	-	
			Thickness	-	6
		2.1.3 Wall_Cast in Place _Strip Footing_ Basement_E_E			
			Length (ft)	80	80

			Height (ft)	13	13
			Thickness (in)	8	8
			Concrete (psi)	-	3000
			Concrete flyash %	-	average
			Rebar	#5	
		Envelope	Category		Cladding
			Material		Brick - Modular (metric)
			Thickness		-
			Category		Insulation
			Material		Polystyrene Extruded
			Thickness		2.64"
			Category		Vapour Barrier
			Material		Polyethylene 6 mil
			Thickness		-
		2.1.4 Wall_Cast in Place _Strip Footing_ Basement_ G			
			Length (ft)	27	33.75
			Height (ft)	6.90	6.90
			Thickness (in)	10	8
			Concrete (psi)	-	3000
			Concrete flyash %	-	average
			Rebar	#5	#5
		2.1.5 Wall_Cast in Place _Strip Footing_ Basement_ H_H			
			Length (ft)	23	23
			Height (ft)	4.6	4.6
			Thickness (in)	2.6	1.6
			Concrete (psi)	-	3000
			Concrete flyash %	-	average
			Rebar		
		2.1.6 Wall_Cast in Place _Strip Footing_ Basement_ M_M			
			Length (ft)	44	55.00
			Height (ft)	17	17
			Thickness (in)	10	8
			Concrete (psi)	-	3000
			Concrete flyash %	-	average
			Rebar		
		2.1.7 Wall_Cast in Place _Strip Footing_ Basement_ P_P			
			Length (ft)	121	151.25
			Height (ft)	15	15
			Thickness (in)	10	8
			Concrete (psi)	-	3000
			Concrete flyash %	-	average
			Rebar		
		2.1.8 Wall_Cast in Place			

		Strip Footing Basement_ R_R			
			Length (ft)	64	64.00
			Height (ft)	7	7
			Thickness (in)	8	8
			Concrete (psi)	-	3000
			Concrete flyash %	-	average
			Rebar		
		Envelope	Category		Insulation
			Material		Polystyrene Extruded
			Thickness		1.5"
		2.1.7 Wall_Cast in Place _Strip Footing_ Basement_ S_S			
			Length (ft)	45	45
			Height (ft)	7	7
			Thickness (in)	8	8
			Concrete (psi)	-	3000
			Concrete flyash %	-	average
			Rebar		
	Concrete Block				
		2.2.1 Wall_Concrete Block_Main Floor_Exterior			
			Length (ft)	546	546
			Height (ft)	13	13
			Rebar	0	0
		Envelope	Envelope Category	Insulation	Insulation
			Material	1/2 "Gypsum Fiberglass board	1/2 "Gypsum Fiberglass board
			Thickness	0	0
			Envelope Category	Cladding	Cladding
			Material	Brick_Concrete	Brick_Concrete
			Thickness	0	0
			Envelope Category	Vapour Barrier	Vapour Barrier
			Material	Polyethylene 3 mil	Polyethylene 3 mil
			Thickness	-	-
		Door	Number of Doors	0	0
		Window	Number of Windows	40	40
		2.2.2 Wall_Concrete Block_Main Floor_Interior			
			Length (ft)	467	467
			Height (ft)	13	13
			Rebar	0	0
		Envelope	Category		Insulation
			Material		1/2 "Gypsum Fiberglass board
			Thickness		0
			Category		Insulation
			Material		1/2 "Gypsum

				Fiberglass board
		Thickness	0	0
	Door	Number of Doors	12	12
	Window	Number of Windows	0	0
	2.2.3 Wall_Concrete Block_Second Floor_Exterior			
	Envelope	Length (ft)	463	463
		Height (ft)	12	12
		Rebar	0	0
		Envelope Category		Insulation
		Material		Fiberglass Batt
		Thickness		2"
		Envelope Category		Cladding
		Material		Brick_Concrete
		Thickness		0
	Door	Number of Doors	0	0
	Window	Number of Windows	40	40
	2.2.2 Wall_Concrete Block_Second Floor_Interior			
	Envelope	Length (ft)	665	665
		Height (ft)	12	12
		Rebar	0	0
		Category		Insulation
		Material		1/2 "Gypsum Fiberglass board
		Thickness		0
		Category		Insulation
		Material		1/2 "Gypsum Fiberglass board
		Thickness		0
	Door	Number of Doors	22	22
	Window	Number of Windows	0	0
	2.2.2 Wall_Concrete Block_Third Floor_Exterior			
	Envelope	Length (ft)	463	463
		Height (ft)	12.2	12.2
		Rebar	0	0
		Envelope Category		Insulation
		Material		Fiberglass Batt
		Thickness		2"
		Envelope Category		Cladding
		Material		Brick_Concrete
		Thickness		0
	Door	Number of Doors	0	0
	Window	Number of Windows	46	46
	2.2.2 Wall_Concrete Block_Third Floor_Interior			

	Envelope	Length (ft)	665	665
		Height (ft)	12.2	12.2
		Rebar	0	0
		Category		Insulation
		Material		1/2 "Gypsum Fiberglass board
		Thickness		0
		Category		Insulation
		Material		1/2 "Gypsum Fiberglass board
		Thickness		0
	Door	Number of Doors	22	22
	Window	Number of Windows	0	0
	Wall _Concrete Block_Fourth Floor_Exterior			
	Envelope	Length (ft)	400	400
		Height (ft)	8.6	8.6
		Rebar	0	0
		Envelope Category		Insulation
		Material		Fiberglass Batt
		Thickness		2"
		Envelope Category		Cladding
		Material		Brick_Concrete
		Thickness		0
	Door	Number of Doors	0	0
	Window	Number of Windows	85	85
	Wall_Concrete Block_ Fourth Floor_Interior			
	Envelope	Length (ft)	977	977
		Height (ft)	8.6	8.6
		Rebar	0	0
		Category		Insulation
		Material		1/2 "Gypsum Fiberglass board
		Thickness		0
		Category		Insulation
		Material		1/2 "Gypsum Fiberglass board
		Thickness		0
	Door	Number of Doors	31	31
	Window	Number of Windows	0	0
	3.1.1 Column_Concrete_Basemnet_ 9			
		Number of Beam	35	35
		Number of	64	64

		Columns		
		Floor to Floor Height	7	7
		Bay Size	10	10
		Span Size	20	20
		Live Load	-	75
	3.1.2 Column_Concrete_Main Floor_6			
		Number of Beam	10	10
		Number of Columns	60	60
		Floor to Floor Height	13	13
		Bay Size	20	20
		Span Size	35.5	35.5
		Live Load	-	75
	3.1.3 Column_Concrete_Second Floor			
		Number of Beam	10	10
		Number of Columns	60	60
		Floor to Floor Height	12	12
		Bay Size	20	20
		Span Size	35.5	35.5
		Live Load	-	75
	3.1.4 Column_Concrete_Third Floor			
		Number of Beam	10	10
		Number of Columns	60	60
		Floor to Floor Height	12.2	12.2
		Bay Size	20	20
		Span Size	35.5	35.5
		Live Load	-	75
	3.1.5 Column_Concrete_Fourth Floor			
		Number of Beam	10	10
		Number of Columns	60	60
		Floor to Floor Height	8.6	8.6
		Bay Size	20	20
		Span Size	35.5	35.5
		Live Load	-	75
	3.1.5 Column_Concrete_Roof			
		Number of Beam	17	17
		Number of Columns	131	131
		Floor to Floor Height	0	0
		Bay Size	20	20

			Span Size	35.5	35.5
			Live Load	40	45
		3.1.5 Column_Concrete_Fourth Floor small bay size			
			Number of Beam	92	92
			Number of Columns	70	70
			Floor to Floor Height	8.6	8.6
			Bay Size	10	10
			Span Size	9.1	9.1
			Live Load	-	75
Roof					
	Concrete Precast Double T				
		5.1.1 Roof_ Concrete Precast Double T_Building Roof			
			Number of Bays	16	16
			Bay Size	20	20
			Span Size	35.5	35.5
			With or W/out Concrete Topping	W	W
			Live Load	40	45
			Envelope Category		Insulation
			Envelope Material		Gypsum fiberglass Board
			Thickness		0
		3.1.5 Roof_ Main Floor_Roof_ Concrete Precast Double T			
			Number of Bays	16	16
			Bay Size	20	20
			Span Size	35.5	35.5
			With or W/out Concrete Topping	-	W
			Live Load	-	75
			Envelope Category	-	Insulation
			Envelope Material	-	Gypsum fiberglass Board
			Thickness	-	0
		3.1.5 Roof_Second Floor_Roof_ Concrete Precast Double T			
			Number of Bays	16	16
			Bay Size	20	20
			Span Size	35.5	35.5
			With or W/out Concrete Topping	-	W
			Live Load	-	75
			Envelope Category	-	Insulation
			Envelope Material	-	Gypsum fiberglass Board

			Thickness	-	0
		3.1.5 Roof_ Third Floor _Roof_ Concrete Precast Double T			
			Number of Bays	16	16
			Bay Size	20	20
			Span Size	35.5	35.5
			With or W/out Concrete Topping	-	W
			Live Load	-	75
			Envelope Category	-	Insulation
			Envelope Material	-	Gypsum fiberglass Board
			Thickness	-	0
		3.1.5 Roof_Fourth floor_Roof_ Concrete Precast Double T			
			Number of Bays	16	16
			Bay Size	20	20
			Span Size	35.5	35.5
			With or W/out Concrete Topping	-	W
			Live Load	-	75
			Envelope Category	-	Insulation
			Envelope Material	-	Gypsum fiberglass Board
			Thickness	-	0
Floor					
	Concrete Precast Double T				
		Floor_Concrete Precast Double T_Main floor	Number of Bays	16	16
			Bay Size	20	20
			Span Size	35.5	35.5
			With or W/out Concrete Topping	W	W
			Live Load	-	75
		Floor_Concrete Precast Double T_Second floor			
			Number of Bays	16	16
			Bay Size	20	20
			Span Size	35.5	35.5
			With or W/out Concrete Topping	W	W
			Live Load	-	75
		Floor_Concrete Precast Double T _Third floor			
			Number of Bays	16	16
			Bay Size	20	20
			Span Size	35.5	35.5
			With or W/out Concrete Topping	W	W
			Live Load	-	75

		Floor_Concrete_PrecastDouble T_Fourth Flooe			
			Number of Bays	16	16
			Bay Size	20	20
			Span Size	35.5	35.5
			With or W/out Concrete Topping	W	W
			Live Load	-	75

Appendix B: Impact Estimator Input Assumption Document

IE Input Assumptions Document - Lasserre

Assembly Group	Assembly Type	Assembly Name	Specific Assumptions
1 Foundation			
	1.1 Concrete Footing		
		1.1.1 Footing _Strip_Basement_F H_H	In The Impact Estimator there is a limitation range of [7.5", 19.7"] for acceptable thickness. In order to find the width corresponding to the corrected thickness the Volume of original footing is calculated and equated to the volume of the corrected footing, to calculate the width related to the corrected volume: 1*2.6*23(ft)=(19(in))⁄12*23(ft)*Corrected Width Corrected Width=1.6 (ft)
		1.1.2 Footing_Strip_Basement_F M_M	In The Impact Estimator there is a limitation range of [7.5", 19.7"] for acceptable thickness. In order to find the width corresponding to the corrected thickness the Volume of original footing is calculated and equated to the volume of the corrected footing, to calculate the width related to the corrected volume: 2*2.2*44(ft)=(19(in))⁄12*44(ft)*Corrected Width Corrected Width=2.78 (ft)

		1.1.3 Footing_Strip_Basement_F K_K	Since the dimensions and material for Footing_Strip_Basement_ F K_K is the same as Footing_Strip_Basement_ F P_P .I have accounted K_K the same as P_P.
		1.1.4 Footing_Stairs_Concrete_TotalLength/Thickness	The thickness of the stairs was estimateded to be 10.5" based on the cross-section structural drawings
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).		
	2.1 Cast In Place		
		2.1.1 Wall_Cast in Place _Strip Footing_ Basement_M_M	• This wall was reduced by a factor in order to fit the 8" thickness limitation of the Impact Estimator for Cast in Place walls. This was done by reducing the length of the wall using the following equation; = (Measured Length) * [(Cited Thickness)/8"] = (44') * [(10")/8"] = 55 (ft) • 6 mm vapour barrier were assumed for all of the Footing_ Strip_ Basement foundations.

		2.1.2 Wall_Cast in Place _Strip Footing_ Basement_ G	• This wall was reduced by a factor in order to fit the 8” thickness limitation of the Impact Estimator for Cast in Place walls. This was done by reducing the length of the wall using the following equation; = (Measured Length) * [(Cited Thickness)/8”] = (27’) * [(10”)/8”] = 33.75 (ft) • 6 mm vapour barrier were assumed for all of the Footing_ Strip_ Basement foundations.
		2.1.3 Wall_Cast in Place _Strip Footing_ Basement_ C_C	• This wall was reduced by a factor in order to fit the 8” thickness limitation of the Impact Estimator for Cast in Place walls. This was done by reducing the length of the wall using the following equation; = (Measured Length) * [(Cited Thickness)/8”] = (362’) * [(10”)/8”] = 452.5 (ft) • 6 mm vapour barrier were assumed for all of the Footing_ Strip_ Basement foundations.

		2.1.4 Wall_Cast in Place _Strip Footing_ Basement_ P_P	• This wall was reduced by a factor in order to fit the 8” thickness limitation of the Impact Estimator for Cast in Place walls. This was done by reducing the length of the wall using the following equation; = (Measured Length) * [(Cited Thickness)/8”] = (121’) * [(10”)/8”] = 151.25 (ft) • Since the dimensions and material for Footing_Strip_Basement_ F K_K is the same as Footing_Strip_Basement_ F P_P .I have accounted K_K the same as P_P. • 6 mm vapour barrier were assumed for all of the Footing_ Strip_ Basement foundations.
		2.1.5 Wall_Cast in Place _Strip Footing_ Basement_ A_A	6 mm vapour barrier were assumed for all of the Footing_ Strip_ Basement foundations.
		2.1.6 Wall_Cast in Place _Strip Footing_ Basement_E_E	6 mm vapour barrier were assumed for all of the Footing_ Strip_ Basement foundations.
		2.1.7 Wall_Cast in Place _Strip Footing_ Basement_ H_H	6 mm vapour barrier were assumed for all of the Footing_ Strip_ Basement foundations.
		2.1.8 Wall_Cast in Place _Strip Footing_ Basement_R_R	6 mm vapour barrier were assumed for all of the Footing_ Strip_ Basement foundations.
		2.1.9 Wall_Cast in Place _Strip Footing_ Basement_ S_S	6 mm vapour barrier were assumed for all of the Footing_ Strip_ Basement foundations.
	2.2 Concrete Block Wall		
		2.2.1 Wall_ConcreteBlock_Main Floor_Exterior	3 mm polyethylene vapor barrier was assumed.
		2.2.2 Wall_ConcreteBlock_Main Floor_Interior	• The interior walls were assumed to be concrete block the same as the exterior walls. • The ½” gypsum board were assumed on both sides of the interior walls. • The main floor plan was very vague and unreadable. Therefore the interior walls length is what I picked up by walking through the building.

		2.2.3 Wall_ConcreteBlock_Second Floor_Interior	• The interior walls were assumed to be concrete block the same as the exterior walls. • The ½” gypsum board were assumed on both sides of the interior walls.
		2.2.4 Wall_ConcreteBlock_Third Floor_Interior	• The interior walls were assumed to be concrete block the same as the exterior walls. • The ½” gypsum board were assumed on both sides of the interior walls.
		2.2.5 Wall_ConcreteBlock_Fourth Floor_Interior	• The interior walls were assumed to be concrete block the same as the exterior walls. • The ½” gypsum board were assumed on both sides of the interior walls.
3 Floor			
	The Impact Estimator calculated the thickness of the material based on floor width, span, concrete strength, concrete fly ash content and live load. The assumptions that had to be made in this assembly group were: 1. Live Load Live load for the main, second, third and fourth floors were assumed to be 75 psi. This assumption was based on the below reasoning In the drawing the live loads are specified as; Classroom: 60 psi Corridor: 100 psi Offices: 50 psi Since there is no option in the Impact Estimator to separate these live loads, The average of the specified live loads was taken which is62.5 psi and 75 psi which is the closet option to it has chosen from the Impact Estimator 45, 75 and 100 psi options. 2. Concrete Strength Concrete strength was assumed to be 3,000 psi. In the drawings there is no specified concrete strength; however they mention that light weight concrete has been used. Light weight concrete generally has strength around 3000 psi which is the reason behind my assumption regarding concrete`s strength. 3. Fly Ash Percentage Fly Ash percentage was assumed to be average, as discussed in the lectures.		
	3.1 Concrete Precast Double T		
		3.1.1 Floor_Concrete Precast Double T_Main Floor	For simplicity the elevation of main floor is assumed to be constant in all classrooms.

4 Roof			
	• Live Load Live load for the roof of the building was assumed to be 45 psi since it is the closet to the specified live load in the drawings which is 40 psi. • Concrete Strength Concrete strength was assumed to be 3,000 psi. In the drawings there is no specified concrete strength; however they mention that light weight concrete has been used. Light weight concrete generally has strength around 3000 psi which is the reason behind my assumption regarding concrete`s strength. • Fly Ash Percentage Fly Ash percentage was assumed to be average, as discussed in the lectures.		
	4.1 Roof_Concrete Precast Double T		
		4.1.1 Roof_ Concrete Precast Double T_Building Roof	For the building roof 4" Polyethylene built up asphalt roof system with 4 " fiber glass felt +gypsum for the insulation was assumed.This combination provides a product that is resistant to moisture and mold as well as fire.
5 Door			
		5.1 Wall _Concrete Block_MainFloor_Exterior	The entrance doors for the main floor exterior walls were assumed as windows because they are doors made out of glass.
6 Column and Beam	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 • Live load Since the live loading was not located within the Lasserre building information, a live load of 75psf on all four floors and the basement level were assumed.		
	6.1 Column and Beam		

		6.1.1 Column _Concrete_Fourth Floor Small Bay Size	For the fourth floor since there are two different span and bay sized. Two conditions for the beam and column section have been created in order to address this size difference. The first set which is the same as other floors and the other set of column and beam which is modeled in the IE as the Column_Concrete_fourth Floor small bay size has different number of columns and beams with different bay and span size. Because of the variability of bay and span sizes in the fourth floor, they were calculated using the following calculation; = sqrt[(Measured Supported Floor Area) / (Counted Number of Columns)] = sqrt[(7101 SF) / (70)] = 10.1 ft