Civil 498C Stage 3 Final Project

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Executive Summary

This report summarises key findings of Civil 498C Studies in Life Cycle Assessment, as we relate them to the various design processes at UBC. Civil 498C has help to lay the background of what LCA means for the future of green engineering and how it's integration will help with new projects. This report will showcase how the integration of LCA can improve UBC's existing environmental action plan.

As the audience is *UBC Sustainability and Engineering department* this report will look at how LCA relates to UBC's building development directly looking at programs like UBC's Climate Action Plan, Building Tune-Up Program, The UBC Vancouver Campus Plan and LCA in the Context of LEED. Building development account for a huge part of UBC's harmful emission which is why it is important for the University to use all the tools at it's disposal, such as LCA. This report aims to rationalize the use of LCA in UBC building design and operation through the existence of campus sustainability programs.

The report will then showcase how the Civl 498C's class study of UBC buildings can be carried out to minimize environmental impacts. Furthermore, the LCA database produced in Civl 498C is analyzed and the outcomes are discussed. Through the database developed from past years in Civl 498C, a benchmark for buildings at UBC can be established. This benchmark sets a value to which new buildings should be compared against. The results of the benchmarking show that the more concrete a building has, the more likely it will have a high impact. Of the materials, concrete, fiberglass insulation, and polyethylene show the largest impacts per unit of measurement (such as cubic meters or square meters), and it is recommended to try to move away from these materials. Recommended alternatives include wood, and new technologies as they become available.

The next steps toward institutionalizing LCA is then discussed. Inaccuracy of LEED is discussed, with emphasis on the lack of absolute values. An idea is proposed for a new database, with local values and more accurate EPDs, working on the fact that the power source for BC is mostly hydropower, and how this will impact different products in a large way. LCA use for whole buildings is paired with LCA of building engineering physics to get a more complete picture. Deriving knowledge from other universities such as Harvard is examined, decoding some of the work that has been done over there. Lastly the use of LCA in other problems, such as waste management, is discussed. This part is left open ended, with the remark that there are countless possibilities to where an LCA study might be done.

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Introduction

The purpose of this report is to evaluate the use, effectiveness, and future of Life Cycle Assessment (LCA) at The University of British Columbia (UBC). This report will be presented to the UBC Sustainability and Engineering department as well as to the Civl 498C Class. Life Cycle Assessment "is a scientific method used to quantify the impacts created by products over their lifecycle"[1], this report will expand on this definition and how it is can relate to everyday design at UBC. UBC Campus is viewed as a living laboratory in which new sustainability initiatives can be tested before being applied on a metropolitan or national level. This report investigates the usefulness of LCA as such a tool. One of the most important things about running an experiment is creating a data set. This coincides with one of the main objectives of LCA. LCA is all about creating and using databases to compare one product to another and track the data over its lifetime. This report aims to rationalize the use of LCA in UBC building design and operation through the existence of campus sustainability programs. The report will then showcase how the Civl 498C's class study of UBC buildings can be carried out to minimize environmental impacts. Finally this report will look at the future of LCA at UBC and potential modeling and education tools. Overall the goal of this report is to integrate LCA into UBC's already diverse and environmentally driven building design operation.

Context for Use of LCA at UBC

"At UBC, sustainability is not just a word to define – it's a word that defines us".[2] Tools like LCA and LEED create simpler way to define what it actually means to be sustainable. UBC has always has always strived to take the initiative on sustainability. As such UBC has started many climate action programs and followed many of the government climate programs. When Canada dropped out of the 2007 Kyoto Protocol, UBC still managed to reach its target by reducing GHG emissions from all academic building to six per cent below 1990 levels. By 2015 UBC hopes to reduce its GHG emission by 33% from its 2007 numbers. Buildings account for over 95% of UBC's Greenhouse Gas emission. Given the aggressive targets UBC has set, this is an excellent time to start thinking about LCA and how it could help reduce this number. UBC campus was constantly expanding between 1997-2007; there was a 35% increase in floor space, and with ongoing construction, that number will keep growing. This constant expansion at UBC needs a standardized environmental LCA for UBC building design and operations. Until ,recently tools to support green or sustainable design were only used in a small percentage of buildings on campus, but this is increasing. LCA provides a simpler, more transparent, and credible methodology that can provide the necessary framework to expand that support[3].

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[1] Sianchuk, Rob. "Week 2: LCA Basics and Development." *CIVL 498C Life Cycle Assessment* 12 (2014).
[2] http://sustain.ubc.ca/campus-initiatives/green-buildings/reap
[3] Ospelt, Christoph. "The Metrics of Sustainable Buildings." *Building Technology Group, Department of Architecture*. *Technical Guidelines*. UBC. Web. 10 Nov. 2014. <http://www.technicalguidelines.ubc.ca/files/sustainable_bldgs.pdf>.

Building Tune-Up at UBC

UBC has started a program called "Building Tune-up (Continuous Optimization)", the goal being to tweak 72 core building on campus to be more environmentally sustainable. The program was piloted in 2010 with Buchanan Tower and Neville Scarfe; through this program UBC saved enough energy to power 30 homes for a year. The program's first phase ran from January 2012 to March 2013 and cost $1.36 million[4].

It is stated that each building optimization will take a minimum of three years, which, when considering construction of a new building is usually between 1-2 years, is a huge amount of time. If an initial LCA is completed on each building before being built, the Tune-up program would function much more efficiently, as linking building materials to their emissions would be easier. LCA is a powerful tool that pays dividends almost as soon as it is institutionalized. If UBC is able to create its own database of buildings, improvements can be readily identified and material options can be compared to historical data. In the future, contractors will be able to give the information on the amount and type of material used, and LCAs will become instrumental tools to reducing future costs and improve the sustainability on UBC's Vancouver Campus.

The UBC Vancouver Campus Plan/ LCA in the Context of LEED

The UBC Vancouver Campus Plan (UVCP) is a guide to the design of buildings, landscape, and surface infrastructure projects within The Campus Plan areas. The UVCP clearly states that all buildings must be designed to achieve LEED® Gold certified standards or approved equivalent. With the recent release of LEED v4, which includes provisions for earning points with LCAs, the use of LCA will help to strengthen UBC's ability to create more sustainable and eco-friendly buildings on campus.

> *"Constructing a building requires the production and transport of products and materials from sectors throughout the economy. These supply chains are so extensive that the "environmental footprint" of a building the day you move in may already be as big as the impacts of heating and cooling and lighting and operating this building"*[5]

This quote, taken from the U.S Green Building Council paper on implementing LCA options in LEED v4, explains the importance of why design guidelines like UVCP need to include LCA; it is important to understand the broader picture of environmental impacts of buildings. Through the use of LCA, the cradle to grave impacts of an entire building can be examined making the broader picture all but crystal clear.Another key UBC guideline is called the Sustainability Best Practice Building Design (SBPBD). which focuses on maximizing environmental sustainability,

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[4] "2011 Carbon Neutral Action Report." University of British Columbia Vancouver Campus. Page 11. Web. <http://www.env.gov.bc.ca/cas/reports/cnar/UBC_2011.pdf>.
[5] "GETTING LCA INTO LEED: A BACKGROUNDER ON THE FIRST LCA PILOT CREDIT FOR LEED®." Web. <http://www.analyticawebplayer.com/GreenBuildings18/client/LCA credit backgrounder Nov13c11.pdf>.

and construction and operation cost efficiencies. SBPBD would benefit immensely from LCA as it can track the environmental and human health impact of the construction supply line, and better understand the true picture of the impact.

Overall, LCA is instrumental to any design guideline or sustainable program, especially here at UBC. LCA creates opportunities to find improvements to the types of materials by showing their true impacts. It also allows for a more educated stream of information through the use of databases and comparisons, allowing users to showcase just how environmentally friendly their buildings are through concrete emission impact analysis.

LCA Study of Academic Buildings at UBC Vancouver Campus

The Civil 498 LCA course is an impressive initiative to study the construction and ongoing impacts of buildings on the UBC Vancouver Campus. It is a course like no other in North America, building on previous years' analysis and results to shape the presentation of data to glean more and more from the raw numbers. The information summary presented here proposes modest changes to building practices, as drastic measures are often met with contempt and disbelief. It is the intent here to begin turning the oil tanker that is current construction practices, towards the end goal of sustainable building planning and development, by gently nudging it in the right direction.

The LCA of UBC's buildings began seven years ago with a class of no more than twenty eager students. The dataset has been further refined over the years and is now at the final stage of the LCA framework: Interpretation. To give context and validity to the results, this paper provides an overview of the methodology of data discovery to interpretation. Following the methods used, the general results and building exclusion notes are introduced. This also includes a summary of impactful materials used in academic building designs, and illustrative tables and graphs. Finally, discussions on the implications of the data are presented with an interpretation of the results, and rules of thumb that can be followed from the trends of the data. The LCA features data collected from 23 academic buildings on the UBC Vancouver Campus.

Methods

LCA truly is an all-encompassing tool used to understand the definitive impact that a new building development might have on the surrounding environment. With the start of this project seven years ago, students began an intensive project that would take almost seven semesters worth of their time to complete. As with any LCA study, it begins by defining the Goal & Scope of the study, which was standardized across 23 building LCAs.

The intended application of the LCA (the Goal) is to create a baseline for the environmental impacts of academic buildings on campus, and provide recommendations to the key decision makers to help them choose environmentally sustainable products for future building projects.

To explore LCA, this course featured three separate stages that built upon each other, and served as introductions to the LCA process. Stage 1 involved the research and reading of current LCA building practices. Five articles from a comprehensive white paper about LCA were summarized and discussed as a group. This process introduced the class to the current state of LCA in the construction industry, as well as the level of communication currently happening. To gain familiarity with the LEED certification process, Stage 2 explored the modification of building materials and envelopes using the Athena Impact Estimator, against a set baseline to attain LEED v4 certification for an assigned building. These assignments culminate with this paper, and the data obtained can now be examined with a prepared mind.

Reliability of Data

To gage reliability of the data obtained from previous years, the impact category totals were compiled into graphs that dealt only with one assembly type. Anomalies were quickly discovered by simply looking at the spikes, and trying to correlate that with the reported material use.

Pharmacy

As a point of illustration, figure 1 shows the graph for assembly type A31: Walls Below Grade.

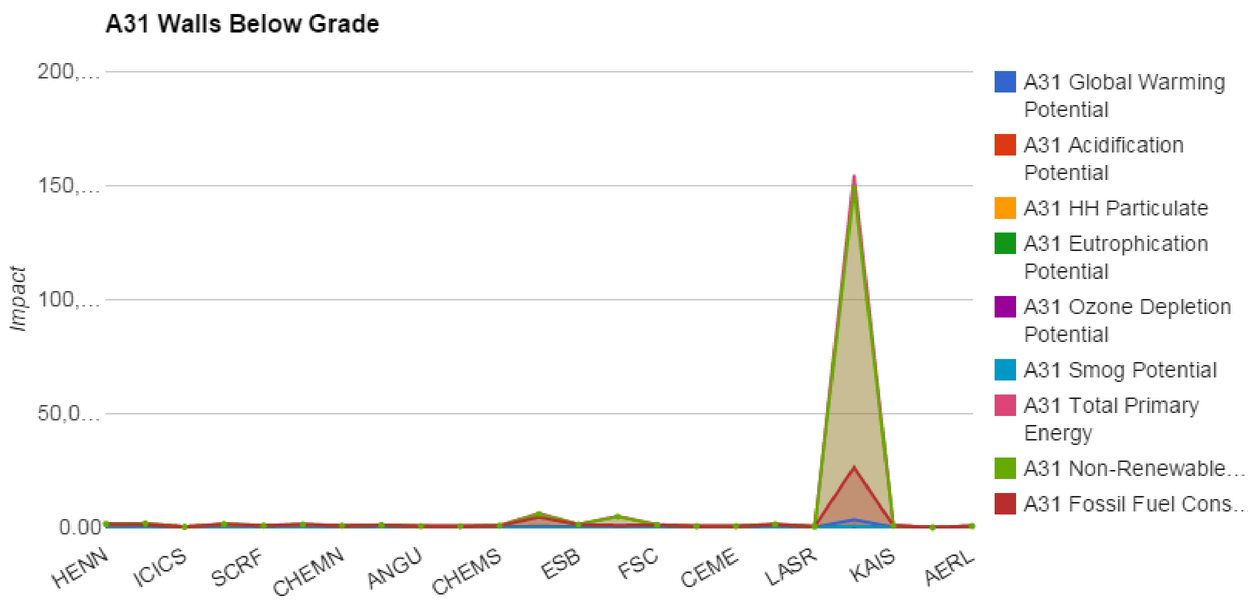

Figure 1: Impact Category values for A31 Walls below grade, all studied UBC buildings

As is clear from the graph, one building is showing clear dominance of the environmental impacts, so what is going on here? The building in question is Pharmacy (PHRM) - a new, $155 million building with huge floor space and a beautiful design. Looking into the PHRM dataset, the Bill of Materials shows a peculiar entry for “Glazing Panel,” which has to do with window panes - why would window panes be in the basement? The information gathered for this LCA study was done in 2013, and fortunately, a copy of the study is easily found located[6]. Reading Annex D - Impact Estimator Inputs and Assumptions of the report shows no input of Glazing Panels either as a material, or as a building envelope, so it is possible to conclude there is no Glazing panel for the A31 Assembly. This throws into question the rest of PHRM's data as having faulty entry into the Athena Impact Estimator. Exploring the graphs further, it is similarly found with the A22 Assembly that PHRM has over 10x the impact of any other building for it's Upper Floor Construction. Reviewing the dataset once again, it is noted that A22's bill of materials again is highly suspect with over 44,000 Tonnes of concrete being used. This number seems extremely high, so PHRM is removed from the dataset entirely for inconsistent performance.

Music Building

The Music building is a straightforward decision to remove from the dataset as it is missing important baseline information. The specific areas for each assembly type has not been recorded, so the Total Effects per m2 is not possible to calculate. Without a proper comparison benchmark, Music is removed from the dataset.

Other building datasets were seen to have anomalies in values, but further investigation showed casual errors in dataset formulas and assumptions. After correction, the anomalies were corrected and the buildings stayed in the set of twenty two. A summary of the environmental impacts and the materials used in academic buildings follows in the Results section.

Results

A summary of environmental impacts, as well as a summary of common materials used, for all buildings studied in this LCA are provided here. The graphs and figures shown below present the total impact for a given category, divided by the given reference flow area to allow for comparison across building sizes; a large building with large impact is not unfairly measured against a small building with a small impact. Each graph is introduced for context.

The results demonstrated here are intended to be different from other students' work. While there are readily apparent comparisons that can be made about building construction year, these comparisons are quickly found in previous years result presentations as well. An introduction to the state of buildings on campus compared to a benchmark of the same is shown, but beyond that the intention is for improvement upon previous interpretations. To provide an in depth look at the environmental impacts, a different variety of tables will be presented.

Benchmark Comparison of Buildings

Averaging the impact categories from all buildings gives a benchmark value for each. This provides a brief introduction to the data. Comparing the building against this benchmark gives a rough idea about how it performs

[6] http://sustain.ubc.ca/sites/sustain.ubc.ca/files/seedslibrary/CIVL498C_2013_LCA%20Report_Pharmacy.pdf

against the UBC 'norm.' Figure 2 below shows the results of that comparison.

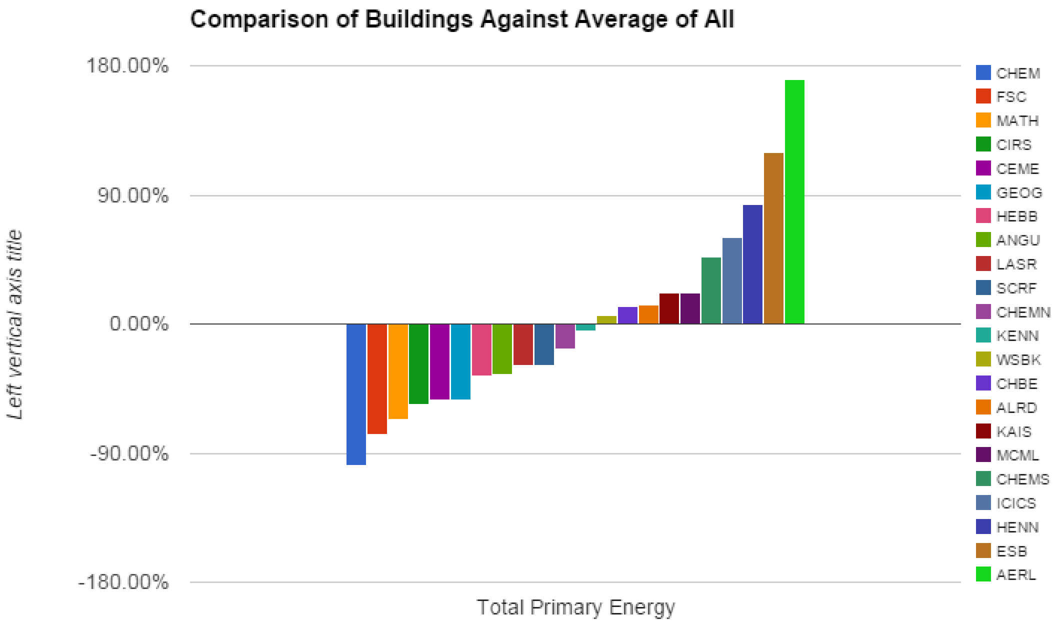

Figure 2: Comparison of buildings across campus against a benchmark, Sean Hudson, UBC

Total Building Impacts

Figure 3 below shows the total building impacts for each of the twenty buildings studied. The bar graph underlayed shows the tonnes of concrete used in each building; initially it was thought that a strong correlation between the amount of concrete used in a building and the impact the building has. This was not an unreasonable assumption, as concrete is very intensive to create, however as the graph demonstrates, no correlation is seen. This type of analysis is provided more in the Discussion section that follows.

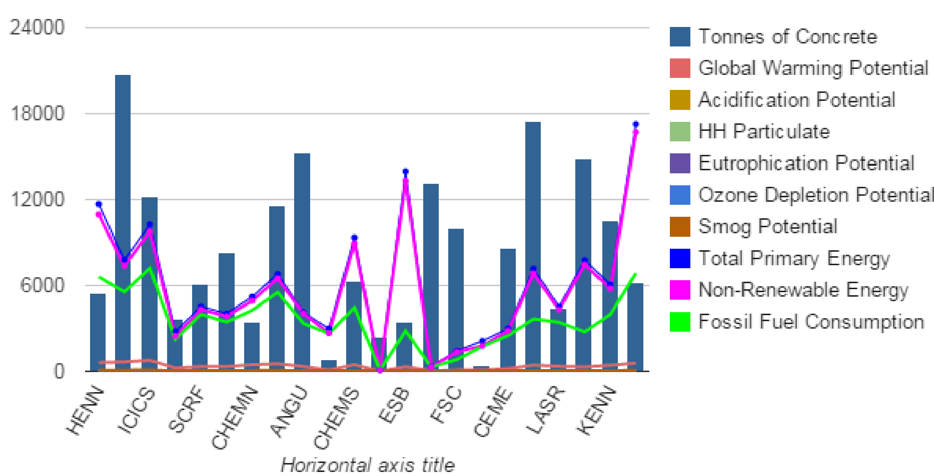

Figure 3: Building Impacts with tonnes of concrete used, Sean Hudson, UBC

Total Mass of Top 15 Materials Used on UBC Vancouver Campus

The following Figure 4 shows the top 15 materials used by total mass. The breadth of this summation spans all buildings studied on campus; the total amount of 30MPa Concrete used amongst all 22 buildings is in the neighborhood of 120,000 tonnes.

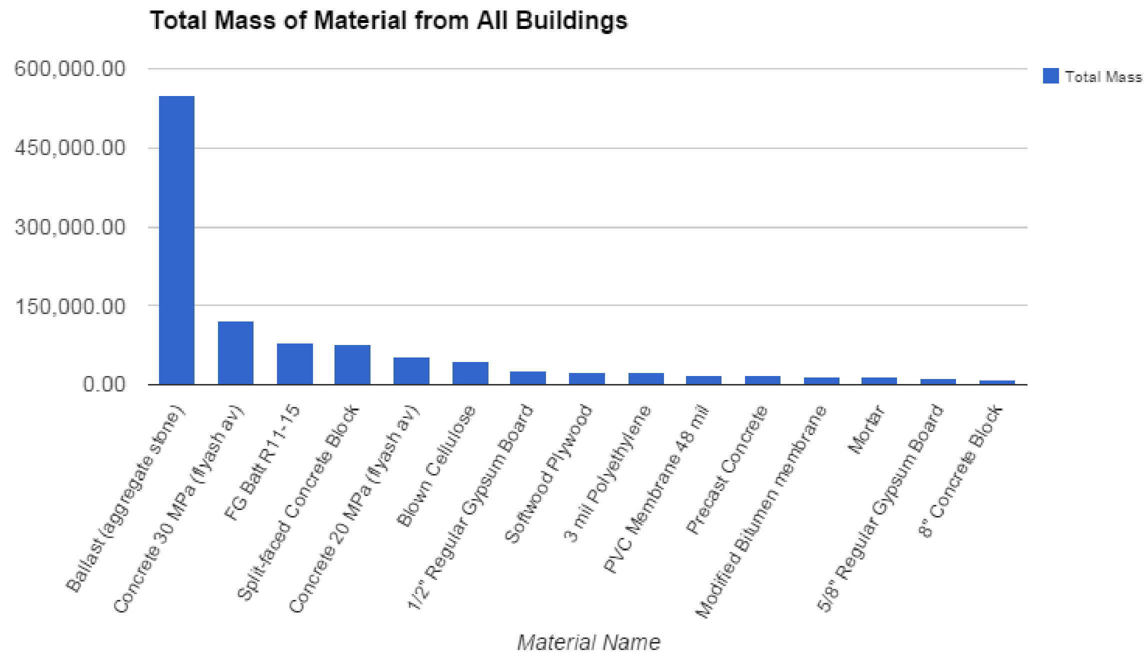

Figure 4: Total Mass of Materials for all buildings, summed, Sean Hudson, UBC

Materials and Their Mass

This is a brief overview of the top 20 materials used in the construction of buildings at UBC. This is to provide the reader with some insight to what the exact mass values are, and what else might be involved in the construction projects. Table 1 illustrates those materials.

Material Description	**Mass (Tonnes)**
Ballast (aggregate stone)	549,506.35
Concrete 30 MPa (flyash av)	121,096.78
FG Batt R11-15	79,403.11
Split-faced Concrete Block	76,162.82
Concrete 20 MPa (flyash av)	53,650.75
Blown Cellulose	43,342.96
1/2" Regular Gypsum Board	26,524.82
Softwood Plywood	24,436.03
3 mil Polyethylene	23,463.18
PVC Membrane 48 mil	18,708.50

Precast Concrete	17,119.72
Modified Bitumen membrane	15,051.29
Mortar	14,829.66
5/8" Regular Gypsum Board	10,744.89
8" Concrete Block	9,518.87
Rebar, Rod, Light Sections	8,101.90
Concrete 30 MPa (flyash 25%)	7,589.75
FG Batt R50	7,525.11
Concrete Brick	6,006.79

Table 1: Top 20 Materials and their weight, Sean Hudson, UBC

Impact Categories for Top 15 Materials by Mass

Next it was desirable to find the total impact of these materials, according to their total mass. This is the absolute impact that the top 15 materials presented to the environment from academic building construction at UBC. Figure 5 below compiles the spreadsheet data generated by the Athena Impact Estimator, and shows the impacts side by side.

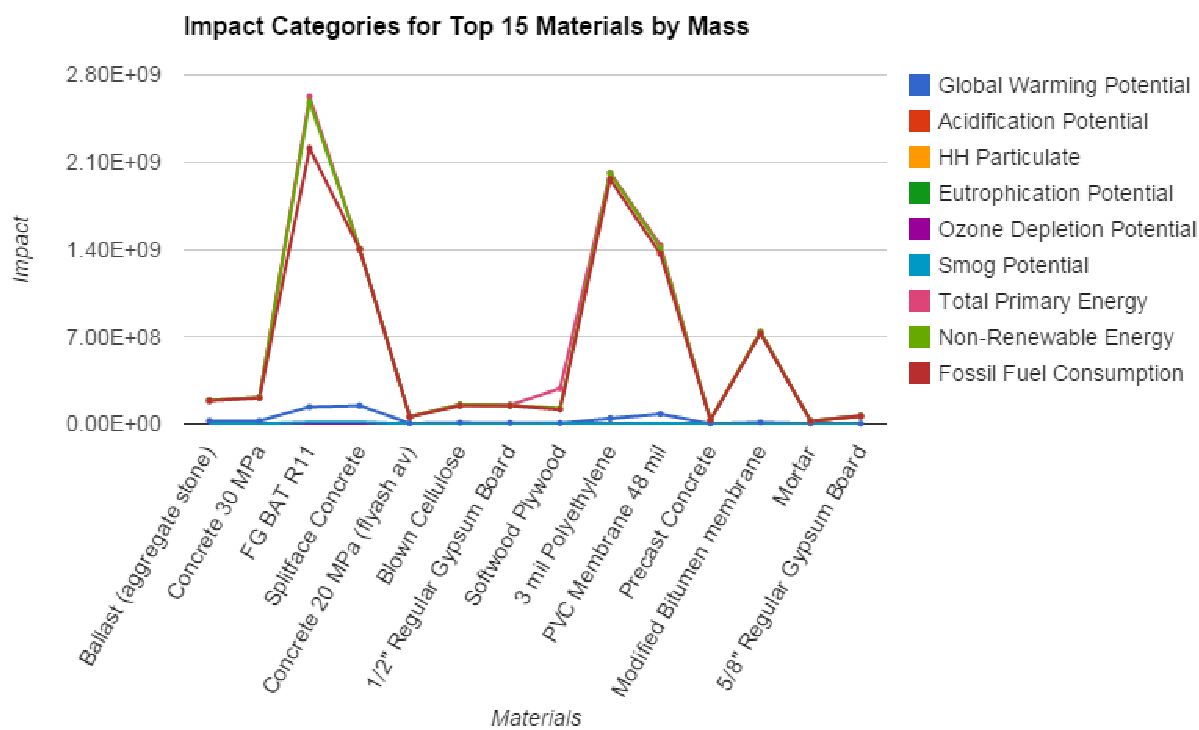

Figure 5: Impact categories of the top 15 materials by mass, Sean Hudson, UBC

Top 15 Materials and their Impact Category per 1.000 Tonne

It can be reasonably assumed that these top 15 materials are important to construction projects, and will likely continue to be in the future. While the total material used is important and shows how UBC's construction habits have impacted the environment, it is necessary to give a comparable baseline for each material. With the baseline it is possible to identify heavily used and highly impactful materials, and phase them out for future projects. For the sake of completeness two versions are shown for baseline comparison; one by weight, one by size. Figure 6 below shows the impact of materials per tonne, where Figure 7, just below, shows the impact per unit of measurement.

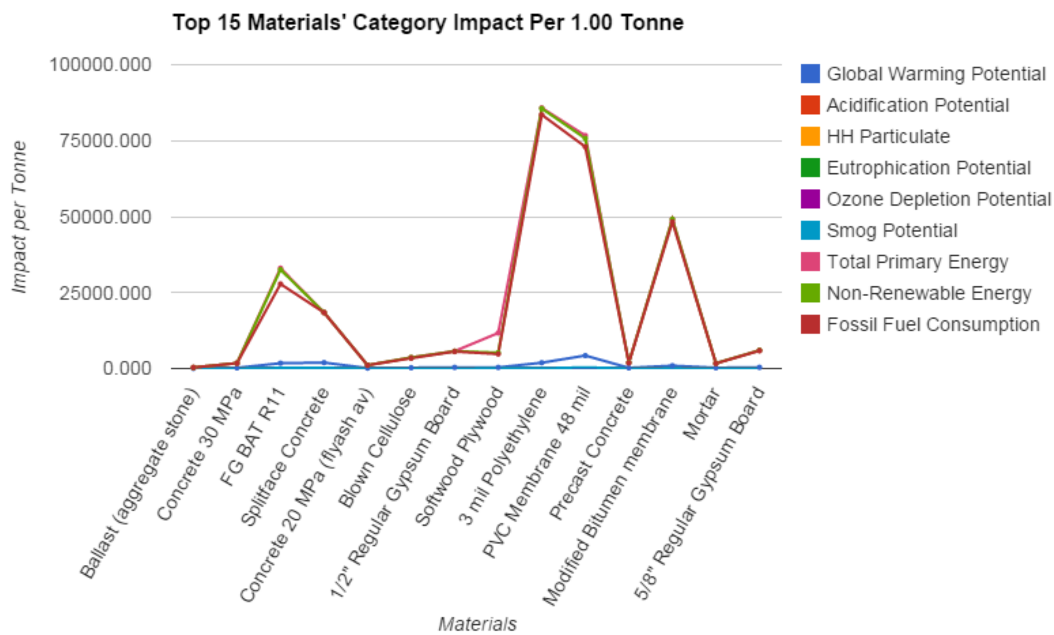

Figure 6: Top 15 Materials' Category Impacts per tonne, Sean Hudson, UBC

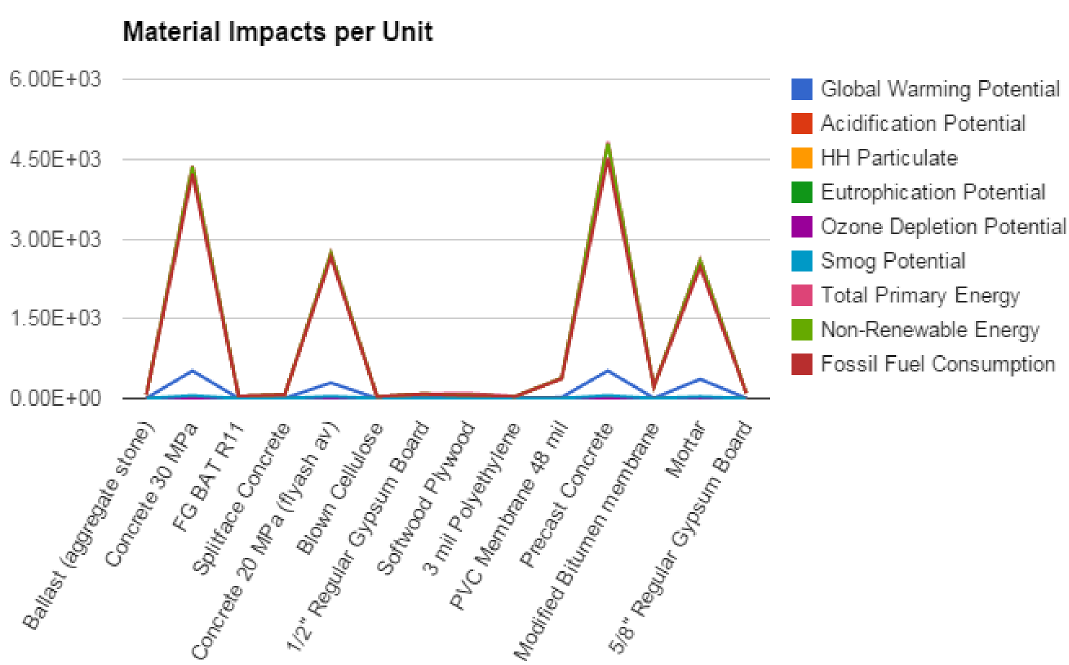

Figure 7: Top 15 Materials and their Impacts per Unit of measurement, Sean Hudson, UBC

These last two graphs can really show the power of Athena's Impact Estimator. The next step is to examine these graphs and their implications with the intention of providing some Rules of Thumb.

Discussions

The results shown above demonstrate many important learning points for building construction at UBC. The interpretation provided demonstrates that it is not always "how much" you reduce, but "of what" that is important. This can lead to some Rules of Thumb to consider when making design decisions in new construction projects at UBC.

Concrete: Hard to replace, but use wood if possible

It is well known in the construction and environmental industries, that concrete is a highly impactful material requiring large quantities of energy to produce. While it might be the recommendation of this paper to reduce concrete usage as much as possible, it is simply not feasible to reduce a building's desire for strong foundations. As is evident by Figure 8, which features construction currently taking place on UBC grounds, concrete will not be easily replaced.

Figure 8: Concrete foundations are poured in new building construction, Sean Hudson, UBC, 19/11/2014

Concrete replacements are many years away, and until those replacements become mainstream it is important to focus on what can be done. That being said, a good rule of thumb is to avoid overuse of concrete in roof and internal structures. Wood is an excellent substitute, as is evident by Forestry Building's excellent environmental performance against the benchmark For current projects involving wood as structural components and roofing components, one need not look further than the new engineering Cheeze building currently under construction on the UBC Vancouver Campus. Figure 9 shows the current state of construction and readily shows the immense use of wood for structural purposes.

Figure 9: Extensive use of wood in structural components of new Cheese building on campus, Sean Hudson, UBC

The Cheeze building is certified LEED Gold, as required by UBC standards. If this is the direction of new buildings at UBC, the future of LCA will remain bright.

Fiberglass Insulation: Reduce where possible, alternatives may develop

The results showed a pretty shocking impact from fiberglass insulation; many tonnes are needed, creating the single largest environmental impact in the Top 15 materials investigated. When looking at the low impacts produced by one square meter of fiberglass R11-15 insulation, it is clear that the impact is the result of the shear volume of insulation needed. It is a difficult tradeoff between possible building energy consumptions and fiberglass embodied energy, but discuss these tradeoffs with the professionals with the intention of reducing the need of fiberglass. Additionally, it is good to note that fiberglass production is one of the leading consumers of recycled glass containers. When recycled material can be repurposed like this, it benefits us all.

3 mil Polyethylene: Reduce consumption

Polyethylene shows up in the Top 15 materials as a highly impactful material, simply because of the volume required. If this material can be reduced, perhaps by replacing with a new material or by reducing waste at the construction site, then another significant impactor can be minimized.

Recommendations for LCA Study

This study brings together an incredible array of data, and should be put to use wherever possible. Just as this class has benefitted from its existence, so can other classes. If LCA is to continue being studied at UBC, other classes can look upon this study as the benchmark in on-campus LCA requirements.

The database allowed this class to perform hypothetical LEED certification of buildings around campus, by utilising the Athena Impact Estimator, and creating a benchmark building much like has been done in this paper. After the benchmark was created, and an assigned building was measured, LEED v4 points were earned by modifying the building construction materials to create a better performing building. This exercise helped focus the intention of the course, and see how the choices made during the design process can drastically effect the impact of the project.

As is stated in the LCA Credit Reference guide, LCA's may reduce the material used, help professionals understand cumulative energy use, and a wide range of other such effects. The inclusion of LCA in the LEED v4 certification signals that the future of green building design will feature Life Cycle Assessments from cradle to grave. It is recommended that UBC becomes familiar with the methods and practices of an LCA. This ensures that when LCA becomes a stronger mainstream idea, UBC can once again be proudly at the forefront of sustainability.

Next Steps for Institutionalizing LCA at UBC

The course Civil 498C has through its 6 years taken UBC a long step towards wider LCA usage at UBC. Moving forward, UBC should try to institutionalize LCA into more and more of its building processes, and get it integrated into the mindset of faculty and staff. This section looks at different steps and ideas to make this happen.

Whole building

This course has focused a lot on LEEDv4, and the certification points from this. One of the drawbacks of LEED is that it deals with relative values, not absolutes. This leaves a lot to the individual building design, with a building being able to perform well in LEED even if it is not particularly sustainable if compared to, say, a zero emissions building. This has its various reasons. Mostly, it's difficult to state matter-of-factly that $1m^2$ of floor in an educational building ought to have a set value for maximum environmental impacts. This is due to the fact that even narrowed down to educational buildings, the difference in usage demands are so great that a threshold value is hard to set. If, however, effort was put into establishing thresholds, a lot could be done. This might be a big undertaking, but with UBC already being on the front line of educational building LCA, it might be a great opportunity. An idea on this could be to section rooms and buildings into different categories, and setting the thresholds for each category. Categories would include lecture halls, reading rooms, library, different types of laboratories and common areas. Establishing and keeping to thresholds could lead to a new ranking system, where the ranking actually says something about the absolute impact level of the buildings.

Another point is that LEEDv4 and the methodology used throughout this course only looks at the building as a structure, and does not take into account the impacts by energy consumption through the buildings lifetime. This could lead to an instance where materials that are chosen might show good performance in the Athena Impact estimator, but give bad insulation performance. This is often mitigated by having a thorough design process where building physics is given its own consideration. However, life cycle energy consumption constitutes a large part of the impact of a building, and should be given its own role in an LCA. Building engineering physics, dealing with light, sound and HVAC, is a complicated field, needing a pretty complete model of a building to provide good data. As this could end up being awfully complicated, general guidelines could be given in an LCA backed threshold. A specification on insulation, heating and lighting systems would add a great deal of sustainability to the buildings. As a whole, this very much lends itself to Building Information Modelling, which is coming up as a big trend in building and structural design. Basically, it takes building engineering physics and combines it with structural drawings and designs in one giant model file.

Databases and models

As far as now, the Athena Impact Estimator has been used as a database tool for LCA. This database provides class EPDs for wide classes of materials. This will not represent every scenario in the most precise way. For instance, BC takes most of its power from hydro. This leads to a different environmental profile of electrical power. If a building erected in BC uses locally manufactured materials, the EPDs for these would arguably look very different from the generic ones found in the Athena database. Using a software where individual EPDs can be implemented will therefore improve accuracy in the LCA studies

Inspiration from Harvard

Harvard University is on the frontier in whole building LCA. They currently have 93 LEED certified projects, more than any other university. Pulling from their advances and knowledge will be most beneficial. There is a lot to be learned only from reading about what they have done and trying to implement similar ideas. The greatest benefit though, would be from having an actual exchange; having one scholar from Harvard on a visit and engage in discussions on LCA.

On their website, Harvard has freely available material on all the projects they have done, complete case studies with information all the way down to EPD level. Looking at Tata hall[7] as an example, this building is certified

[7] http://www.energyandfacilities.harvard.edu/green-building-resource/leed-case-studies/tata-hall-hbs

Platinum in LEEDv3 for new construction. It is a 14280m2, 7 floor multiuse building at Harvard Business School. 55 % of woodwork used is FSC certified, and a lot of the material is post-consumer and locally manufactured. The inside of the building is filled with innovations such as daylight and motion sensors for turning on and off the lighting and HVAC system. Another major concern was stormwater system. This was met with a green roof, naturally filtering filling material and a 48 % reduction in water use by the means of low-flow appliances and fixtures. This is solid LCA work from start to finish, where everything has been taken into account.

Making a similar database for UBC will help show the effort and put the LCA mindset on everyones agenda. Harvard has a green building standard that all capital projects at the university must apply by[8]. One of the central ideas of this document is the integrated design. This is the idea that LCA is something to be done holistically, spanning different disciplines and aspects of the building. There is also a part on energy modelling, using mathematical models to look at the energy consumption of the building. This also adds to the wholesome approach, not only looking at the building as an inanimate object, but as an organism that will consume energy and produce waste.

Other products as a target for LCA

The focus of the efforts so far has been on buildings, as this is maybe the component where the largest impact can be made. There are however many more areas where the environmental impacts from UBC could be reduced by the use of an LCA approach. This is where the genius of LCA comes into play. If you can measure it, you can do an LCA study.

There is already a good recycling system at UBC, with 4 types of refuse bins next to each other at major locations. In waste management, the mantra has always been reduce, reuse, recycle. Many have forgotten the first two, which is highly unfortunate, since this is where the largest impact reduction can be made. Students are a large, often unruly group of individuals. Enforcing a reduce-type policy on students will prove quite difficult. The next natural step is to go to is the source. UBC has already thought in these lines, with enforcing the payforprint program, aiming to reduce the impact and cost of printing. Similarly, steps could be taken to all food and beverage venues at campus, encouraging or enforcing packaging restrictions or specifications. As seen in the history of LCA, one of the earliest examples was beverage containers, so this is clearly feasible. The next step from here is knowing what happens to our waste. How much of it will end up as compost? How much will be recycled? And how much will end up on the landfill in Delta? These are question fairly easily answered. The real problems comes with comparing the alternatives. Is it really so bad if everything in the black bin goes to the landfill? This is where LCA can help us. Comparing different waste systems lends itself to LCA very quickly. There is often a vast jungle of contractors and subcontractors in the waste industry, but if you can wade through it, often you will find a lot of

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8 http://energyandfacilities.harvard.edu/sites/energyandfacilities.harvard.edu/files/Harvard%20Green%20Building%20Standards_February%202013.pdf

surprises. For the longest time, paper sent to recycling in BC got shipped to China. There, it was repulped, mixed with Chinese recycled paper and shipped back to BC to be new newspapers. This will simply not give a good LCA score, and should be looked into. The ability to apply LCA to anything that is measurable is what makes this tool so powerful.

Conclusion

It is clear that the case for LCA at UBC is strong. By leading the sustainability charge here at home, and providing new frontiers for students from all over, UBC has set itself up to live in infamy for its groundbreaking work. It should be clear now that UBC is the ideal incubator for such a great sustainability tool. The recommendations provided here are a small step towards improving the ecological footprint of all students at UBC, and are hoped to prompt eyes to the horizon for emerging materials and technologies. With world-class schools such as Harvard leading with excellent examples, UBC must adopt LCA as a standard in building construction to remain at the forefront of sustainability.

The infrastructure for UBC to adopt a program such as LCA into its building design practices already exists. It exists in the many forms of sustainability initiatives set out by the university over the recent years. These initiatives were set by ambitious people who want to show the world what a forward thinking, sustainable campus UBC actually is, and LCA is the chance to do just that. By following the maxims set by school leaders, this Civil class has taken the important first step towards institutionalizing LCA at the UBC Vancouver Campus.

The dataset built over the previous six years shows important trends in the material choices made for buildings. While concrete is an essential tools for construction, its impacts are widely known and its use should be limited to foundational and structural forms. In its place, wood serves as an excellent partition for interior walls, and showcases the natural beauty of UBC's surroundings. It was noted that insulation is a highly impactful material, simply because of the volume required to complete a building. While fiberglass is a large consumer of recycled glass, it is important to keep abreast of developments, such as Mineral Wool and other emerging sustainable materials.

Looking forward to the future of LCA at UBC, the future is bright. Impact Estimator tools are getting better every day, and the uptake of LCA is similarly increasing. As LCA gains notoriety, UBC will be well served to continue its path of encouraging and fostering LCA as a standard practice. This fostering of LCA will land UBC among the ranks of Harvard in terms of sustainability. It is even possible for UBC to one day contribute to LCA databases if programs such as this continue.

It is evident that the increasing emphasis on LEED certification will no doubt cause UBC to review their building standards once again. When this occasion does occur, it is imperative that UBC include LCA as a standard in building design and maintenance plans.

Annex A

Brady DeSantis-26511105

Through my undergraduate education I have been exposed to various courses on sustainability. Last year I took CHBE 484 (Green Engineering Principles and Applications for Process Industries) that course focused more on comparing consumer products. CHBE 484 gave me good background knowledge of LCA and what to look for when tired to evaluate emissions. I would say that Civl 498C focused more on the tools and data involved with LCA where CHBE 484 focused more on the definitions and content surround LCA.

The reason I chose this course is because I feel that LCA is an instrumental tool in green engineering. I hope to one day go into the Oil & Gas sector and I think that it is important to have a strong understanding of how emissions can be reduced in order to better the future. As well I was interesting the use of excel and I think not enough courses use excel and it is important to get some experience using heavy set of data. For the final project I enjoyed researching the various sustainable programs here at UBC and better understanding the campus environmental goals. I think that a lot of the hype around "going green" is mainly for marketing purpose, so it is always refresh to look at concrete fact and data showing that thing are actually changing both on campus and all around Canada. Overall the class and the project I believe will be extremely helpful in my future as we learned a lot of relevant information of LCA and tools involved with LCA such as excel and ATHENA. I have found that at UBC there is not that much emphasis on databases and using computer skills to help with the work we do. I think this class/project is interesting because it allows to to use some of the major equations and calculation we have learn in our undergraduate degree and use the computer apply them to larger databases.

Eirik Leknes - 55452149

I have had little real experience with LCA from before, we had it as one of many subjects in a course. I had knowledge of the concepts, but not much in the details. This course has shown me the inner workings of a whole building LCA, as well as looking at the broader perspective. Putting LCA into a global context has been important, trying to draw experience and practices from other parts of the world.

What I really liked in this course is that we dug so deep into the material. Often LCA is a thought process and a “soft” subject, with little “hard” facts. Here we used real data and a real impact estimator, learning the process and everything that goes with it. This supplied by the more overviewing knowledge from the lectures gives me wide understanding of LCA as a tool and whole building LCA especially.

One of the wonders of LCA that I realized through the course was the idea that if you can count it, you can do an LCA study on it. LCA is often used in big decisions, whole buildings, bridges and structures. One could also apply LCA to smaller things, all the way down to everyday things such as paper airplanes. The key is that you can do accounting for something other than monetary value. Paralell to this course, i have taken CIVL 564 Engineering Management of Solid Wastes, and I see that LCA really lends itself to solid waste management. This is also one of the first fields where I heard about LCA, comparing an incinerator to a composting plant for food waste. Earlier years, i have taken a few transport and road courses, and I really see the use of LCA also in this field. Most fields are governed by money, and there is a lot of engineering economics in both transport and structures. Using LCA as a guiding tool to sustainability in these fields

Sean Hudson - 28556116

For myself, the practice of LCA is an old paradigm of thinking with a new name. The cradle to grave mentality has been introduced to me a number of times throughout my life, but it has never been given a formal name. It seems like second nature to include the total impacts of all materials by now, but sadly this isn't always the way. LCA was used by other names to demonstrate the potential downsides of certain technologies to those who are otherwise oblivious. My favorite example of this is from a number of years ago.

The Chicago Transit Authority decided that propane busses were great for marketing a green image, so they purchased a number of busses that run on propane. The busses were widely heralded as efficient machines that produced very little green house gas emissions, and the people of Chicago recjoiced. My interest peaked when an article surfaced summarizing the highly polluting process of creating propane. These busses were lipstick on a pig! The act of producing propane far offset any benefit gained by burning it as fuel. This is just one example in a laundry list of LCA discoveries that are not formally named as such. Other examples include the pollution heavy process for generating solar panels, or high performing batteries. These sacrifices are necessary to improve the underlying technology, but it is important for adopters of "clean" technology to be sure they are in fact clean.

The formal introduction of LCA has been a great way to formalize the thoughts and feelings I had around these revelations; a process to actually evaluate and question popularly held beliefs. With the introduction of LCA from this course, and after watching a few eye-opening movies (180 South is a fantastic documentary about the industrial exploitation of Chile and Patagonia. Additionally Interstellar was provoking for its portrayal of a world consumed by dust storms and mass hunger, though it might be Hollywood-ized), I have given serious thought to the impact of my everyday choices and purchases.

I hope to one day see the EPD available for a new MacBook, or pair of glasses. I feel EPDs will go a long way to helping people justify an increased cost for particular goods or services, by demonstrating **why** something might be more or less expensive. I had a daydream the other day where currency was replaced with the notion of carbon credits for certain services. What if instead of paying for Car2Go with money, it is deducted from a certain allotment of carbon points I get each month? This is a pretty extreme idea, and not likely to sit well with many people, but I feel the introduction of LCA from this course has given me pause for this kind of considerations. If the word of LCA spreads to more people, perhaps there will be a greater appreciation for choosing one product over another. When this day comes, people might truly understand the implications of long term effects.