Life Cycle Assessment at UBC

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Exectutive Summary

LCA, a scientific method for measuring the environmental footprint of materials, products, and services over their lifetime is an underutilized tool in the design of buildings at UBC. To better implement LCA in UBC's current documentation, LCA should be required in the same way that LCC principles are already required for selection of materials and equipment. Additionally, the LCA technique could be used to ensure that buildings are designed to consume as little energy as possible. Environmental Product Declaration (EPD) available could be required to ensure that manufacturers who have developed product environmental impact reports are preferred.

In the LCA study of academic buildings on the UBC Vancouver campus, an overall benchmark of environmental impact performance was created and "hotspots" were identified where improvements could be made to reduce the environmental impact potential these buildings had. In addition to the overall building benchmark, further analysis was done on benchmarking each element of these buildings to pinpoint the sources of these hotspots. Furthermore, the quality of the data was taken into consideration and major errors and assumptions were identified in both the database and the Athena Impact Estimator software, respectively.

Finally, in taking the next steps in institutionalizing LCA at UBC, it was found that clear guidelines for Goal and Scope of an LCA should be created, so that all future analysis is based on the same benchmarks. Furthermore, a database of information on campus building performance should be developed and shared within the broader educational community to promote progression within the LCA subject.

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Introduction

The Athena Sustainable Materials Institute defines Life Cycle Assessment (LCA) as “a multi-step procedure for calculating the lifetime environmental impact of a product or service”[1]. Unlike many other “sustainability” tools, LCA is a scientific method for measuring the environmental footprint of materials, products and services over their entire lifetime. The LCA process includes a goal and scope definition, inventory analysis, impact assessment, and interpretation. In the past decade LCA has become increasingly popular as the general public has become more focused on the environmental impact of the things we surround ourselves with. However, the LCA process has yet to be widely used in building design.

This report will first explore the extent of which LCA has been included in UBC building projects, and how LCA is incorporated into UBC’s sustainability programs such as the UBC Climate Action Plan, UBC Vancouver Campus Plan - Part 3, UBC Technical Guidelines, and UBC RFI Evaluation Criteria. In the programs where LCA is not explicitly stated, this report will propose the extent of which LCA could be incorporated to further strengthen the sustainability aspect of the programs.

In the second section of this report, we will outline how an LCA study of academic buildings at UBC can give new insight to environmental impacts in the existing UBC building portfolio. By looking at both the overall impact assessment of UBC buildings, and each element with respect to every impact category, environmental impact “hotspots” will be identified.

Lastly, the report will highlight the next steps for institutionalizing LCA at UBC. Promising LCA communication and education resources, LCA modeling tools, LCA databases, and LCA decision making methods will be discussed. Recommendations will be made based on these discussions.

1. Athena Sustainable Materials Institute. (n.d.). LCA, LCI, LCIA, LCC: What’s the Difference? Retrieved November 18, 2014, from http://www.athenasmi.org/resources/about-lca/whats-the-difference/

Context for Use of LCA at UBC

LCA, Life Cycle Assessment, has sparked the interest of many institutions in recent years. At UBC, the ISO standardized technique to assess environmental impacts associated with all stage of a product's life has only been used at a limited degree in some recent building projects.

"LCA study of the UBC District Energy Centre - Hot Water Plant" by Coldstream Consulting[2] is one of the most recent examples of an LCA analysis performed on a new UBC building project. In this study, a cradle-to-gate LCA was performed on two proposed District Energy Centre structural systems options - one structural steel system and one engineered wood product and steel "hybrid"system. By analyzing the proposed building material and energy inputs of both systems, Coldstream Consulting found the hybrid system showed a 26% reduction of global warming emissions compared to the structural steel system. The hybrid system also showed reductions of 18% to 64% for other environmental impacts, which included indicators such as fossil fuel use, acidification potential, eutrophication potential, ozone depletion potential, smog potential, and human health criteria pollutants. Together with a Life Cycle Costing model developed for the two systems, this study provided the Design Energy Centre stakeholders with a highly valuable economic-environmental impact comparison to aid the design decision-making process.

LCA can also serve as a scientifically based comparison tool for evaluating environmental impacts of building renovations. One of the best examples of using LCA for this purpose at UBC is in the 2006 Life Cycle Assessment report of the Buchanan Renovation Phase 1 – Building D project[3]. This report, created by architectural and engineering consulting company Busby Perkins+Will, compared the life-cycle implications between the renovation project and a new building project that would involve demolishing the existing construction. By looking at Primary Energy Consumption, Global Warming Potential, Index of Air Pollution Effects, Index of Water Effects, Natural Resource Use, Weighted Resource Use, and Solid Waste, Busby Perkins+Will found that there are environmental tradeoffs for both the Renovation and the New Construction option. However, a significant amount of energy, resources and pollution is embodied within the existing building, as most environmental impacts are as a result of the manufacturing of the building materials and the

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2. Coldstream Consulting Limited. (2013). LCA STUDY OF THE UBC DISTRICT ENERGY CENTRE – HOT WATER PLANT. Vancouver, BC.
3. Busby Perkins + Will. (2006). Life Cycle Assessment - Buchanan Building D. Vancouver, BC.

construction of the building. Large amounts of waste, water pollution and resource-use are avoided by retaining and reusing components.

As these two examples show, there is good promise in using LCA as a value-added design tool for UBC's infrastructure projects as it helps designers more clearly understand how different materials and building methods impact the environment. However, until now little has been done to include LCA in the UBC sustainability programs that affect buildings. The remainder of this section will therefore focus on how LCA can add value to these sustainability programs, and how LCA can make these programs more relevant for assessing the environmental impacts of UBC's building projects.

Climate Action Plan

In 2007, the Province of British Columbia legislated province-wide GHG emissions reductions targets and imposed all public sector organizations, including UBC, to become carbon neutral by 2010[4]. This was one of the actions that led UBC to create the Climate Action Plan, which outlines climate change mitigation strategies for the UBC Vancouver Campus[5]. As part of this document, the university developed four main visions for addressing climate change:

1. Become a new positive energy producer by 2050.
2. Partner for change.
3. Use the campus as a living laboratory.
4. Account for the full costs of our decisions.

As part of the process in addressing these visions, the university has promised to report on the energy and GHG emissions inventory. Albeit far from an LCA process, this is the closest the Climate Action Plan comes in incorporating the principles of LCA.

As one of the most impactful UBC sustainability programs, the Climate Action Plan could see great benefit in incorporating LCA as part of UBC policy. Specifically, in section D of the Campus Development and Infrastructure Actions Implementation Matrix, it is mentioned that UBC will "Develop a LEED® Guide to identify optional LEED® points that are a priority for UBC (e.g. energy

4. Province of British Columbia. (2007). BILL 44 — 2007 - GREENHOUSE GAS REDUCTION TARGETS ACT. Retrieved from http://www.leg.bc.ca/38th3rd/1st_read/gov44-1.htm
5. University of British Columbia. (2010). Climate Action Plan. Retrieved from http://sustain.ubc.ca/sites/sustain.ubc.ca/files/uploads/CampusSustainability/CS_PDFs/PlansReports/Plans/UBCClimateActionPlan.pdf

and atmosphere) and to share lessons learned to date to guide consultants through LEED® certification at UBC."

It is advised that UBC not only fully incorporates whole building life cycle assessment criteria of LEED v4 'Building life-cycle impact reduction - Option 4', but goes beyond this by requiring LCA to be performed in all major UBC building projects, including renovations. This will in effect touch on all the four Climate Plan visions in the following way:

1. Become a new positive energy producer by 2050. LCA would aid designers in understand how to best lower energy demand for different UBC buildings.
2. Partner for change. With LCA studies being mandatory at UBC, this will help institutionalizing LCA in the broader building design and construction industry.
3. Use the campus as a living laboratory. Easy to use LCA design tools could be developed and implemented at UBC.
4. Account for the full costs of our decisions. LCA is a scientific way of understanding the full environmental "costs" of building project decisions.

UBC Vancouver Campus Plan - Part 3, Design Guidelines

UBC Vancouver Campus Plan - Part 3 outlines design guidelines that have been developed as a toolkit to help coach, coordinate, and regulate project design throughout UBC Vancouver Campus[6]. Project designers can use this document to aid their building design process, making sure they comply with all the regulations set by the university.

Section 2.1 of the design guidelines highlight the regulations on sustainability measures in UBC building designs. Even though this section highlights the fact that "all projects must be designed to integrate sustainable best practices in design", it fails to mention LCA as a possible design tool for achieving this. It is highly recommended that LCA is included in this section, highlighting the fact that LCA is an ISO standardized process for accounting for environmental impacts of building projects. Including LCA in the design guidelines would make the technique more known to the design consultants, staff, project sponsors, and members of the broader UBC community.

6. UBC Campus and Community and Planning. (2010). Vancouver Campus Plan - Part 3: Design Guidelines. Retrieved from http://planning.ubc.ca/sites/planning.ubc.ca/files/documents/planning-services/policies-plans/VCP_Part3.pdf

UBC Technical Guidelines

The UBC Technical Guidelines was developed for architects, engineers, and contractors to understand the code of quality and performance required by UBC`s institutional buildings, including housing, athletics and institutional buildings[7].

There are several loose references to LCA in the UBC Technical Guidelines, but unfortunately, some of them are confusing LCA with LCC (Life Cycle Costing). Specifically, in the section on Life Cycle Costing Toolkit[8], a life cycle analysis discussion document, "The Metrics of Sustainable Buildings", is pointed to as a reference for LCC. While LCA and LCC both take life cycle approaches in their analysis, they look at very different impacts (environmental impacts versus monetary impacts).

Based on our analysis, there are two main sections of the UBC Technical Guidelines where LCA could be incorporated with great value:

1. *Performance Objectives*. LCA should be required in the same way that LCC principles are already required for selection of materials and equipment. In addition, LCA could be used as a tool to ensure that the goal of healthy buildings (buildings that do not negatively affect human health) are met.
2. *Sustainability*. The LCA technique could be used to ensure that buildings are designed to consume as little energy as possible. Further, materials with Environmental Product Declaration (EPD) available could be required to ensure that manufacturers who have developed product environmental impact reports are preferred.

UBC RFI Evaluation Criteria

UBC develops Request for Information (RFI) documents for the purpose of collecting written information on capabilities of various suppliers in relation to upcoming building projects. As part of this, certain evaluation criteria for the responses are developed.

Some of the current RFI documents, such as the RFI for "Architect and Consultant Team - Old SUB Building"[9], mention that developing a life cycle assessment of project options and their costs

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7. UBC Building Operations. (2014). UBC Technical Guidelines. Retrieved November 15, 2014, from http://www.technicalguidelines.ubc.ca/index.html
8. UBC Building Operations. (2014). Life Cycle Costing Toolkit. Retrieved November 15, 2014, from http://www.technicalguidelines.ubc.ca/technical/life_cycle.html
9. UBC Payment & Procurement Services. (2013). Request for Information (RFI) # 2013010129 Architect and Consultant Team - Old SUB Building. University of British Columbia.

is a key part of the RFI response evaluation criteria. This is one of the only references to LCA of the UBC documents studied in this report.

Including LCA as part of the RFI evaluation criteria is very valuable, as it will show that suppliers (such as consultants) with LCA expertise have a competitive advantage in the UBC building project market. This move will help suppliers see the value of investing in knowledge on performing LCA studies.


Faculty of Forestry
Canfor Theatre

LCA Study of Academic Buildings at UBC Vancouver Campus

The study of the academic buildings at UBC were split up into 2 stages. In stage 1, data for 24 buildings on UBC's Vancouver campus were evaluated based on construction elements and whole building analysis. The data was analyzed using the Athena Impact Estimator and the total effects per square-metre were determined for each impact category (based on TRACI). In addition to the impact categories, the materials used in each element and their mass values were also retrieved from the Impact Estimator. The data from the Impact Estimator provides the emissions equivalent based on a specific impact category (i.e. Global Warming Potential in CO2, Eutrophication in N, etc.) needed in order to complete an inventory analysis on the different Lifecycle stages (i.e. Product, Construction Process, etc.). This data is then standardized for every element in every building based on the number of square-metres each element is. This way, an average of the environmental impacts for each building and each element of each building can be obtained in order to compare building performances.

For stage 2, the standardized data for every building was taken and a baseline average for all 24 academic buildings were developed. With this possible to compare the results of one building to the average and determine what changes could be made in order to improve the performance rating of the building. Although a comparison was made for each element of a building to that specific elements' baseline, a proposal for improvement was made only on the data of the whole building. In LEED v4, 3 points are given if environmental impact for at least three categories are lower than 10% from the baseline data. To improve the building performance, a proposal was made for the building by adjusting materials used in the building in order to reduce the quantitative environmental impact seen in each impact category. The improved performance obtained from the Impact Estimator for the proposal was then compared to the original results of the building - the new baseline. It is important to note, however, that the benchmark that was created from the 24 buildings studied at UBC didn't necessarily include data from all of the buildings. For example, the Hennings and Pharmacy building were left as their values were vastly different relative to the other buildings and were considered outliers. These buildings also had inconsistent data in their respective Bill of Materials. In addition to the above two mentioned buildings, the Music building was also excluded from the data, as it was found to have missing data in the original database, including missing values for the floor area of each element. As a result, 21 buildings were evaluated for environmental impacts.

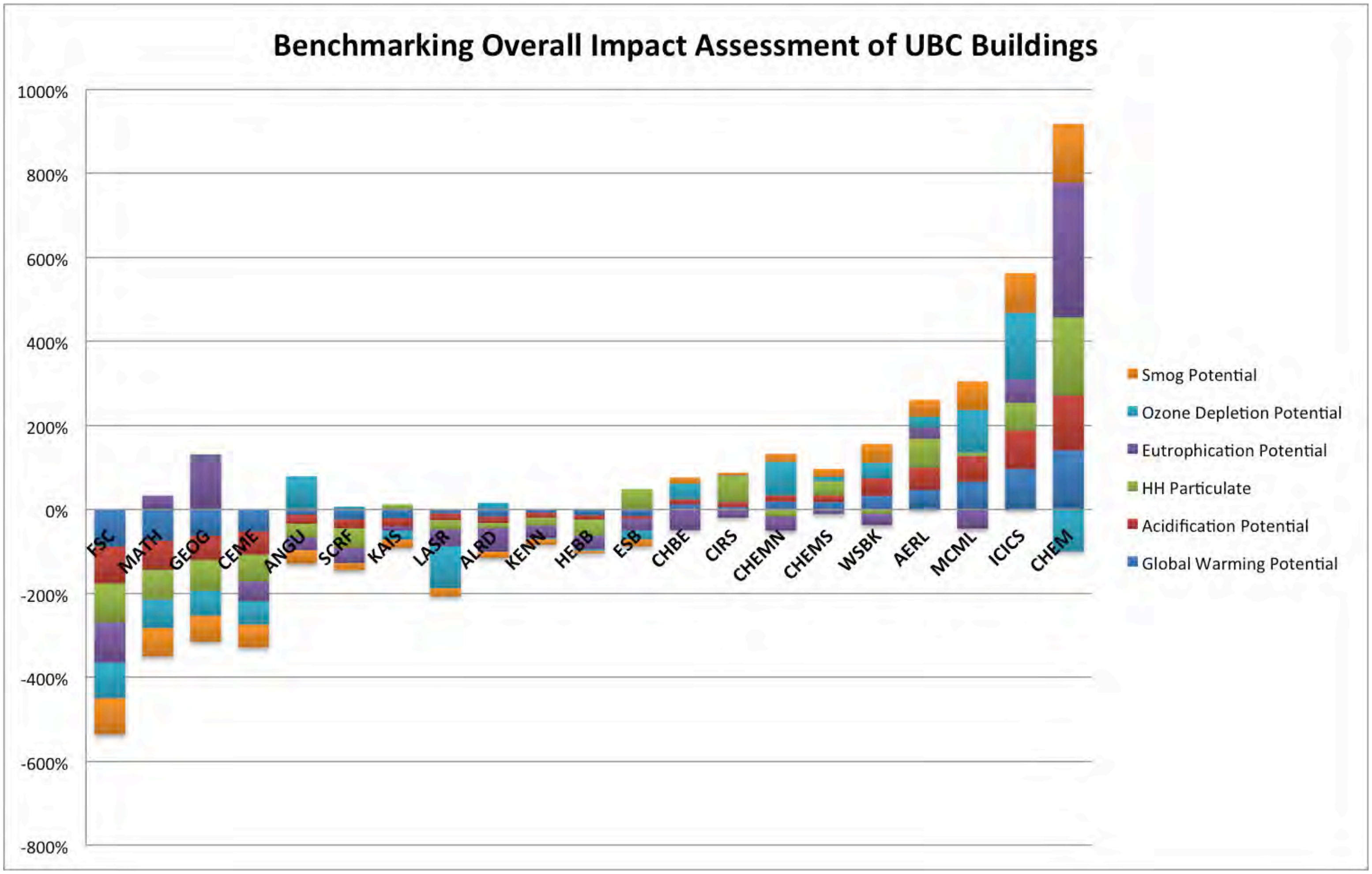


Figure 3 - Benchmarking overall environmental impact of UBC buildings against baseline average

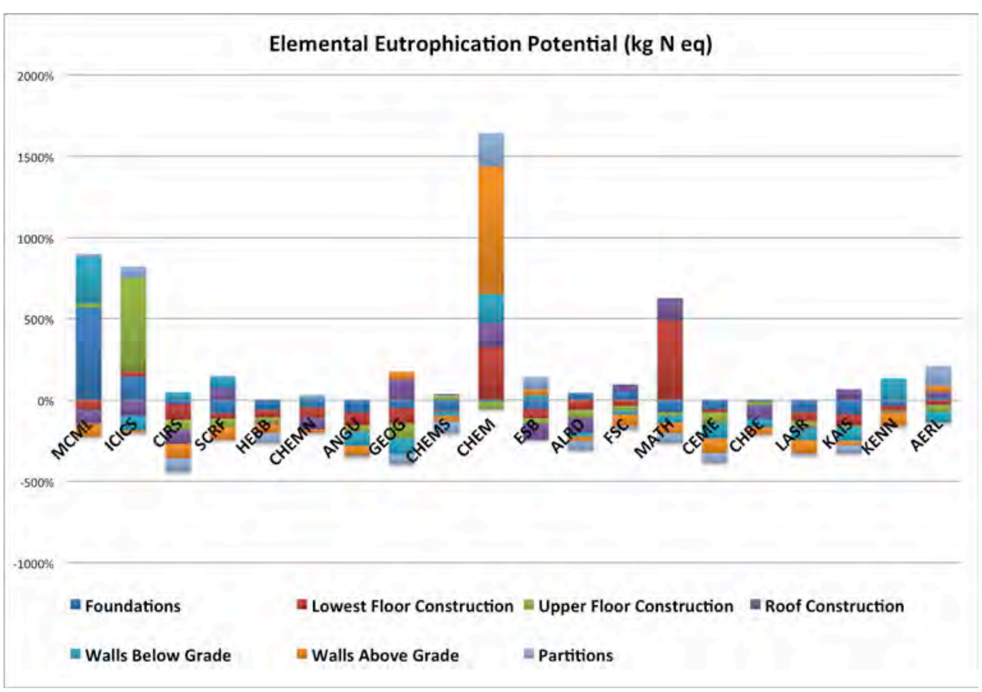
Figure 3 provides a visualization of the performance of each UBC building studied with respect to the benchmark calculated from all of the buildings that were analyzed. Amongst the oldest buildings, CHEM, has the worst performance in the majority of the categories while FSC, a newer building, has the best performance. The results scattered in the middle portion of the graph include buildings such as ESB, CHBE, and CIRS which are very new buildings at UBC. It would have been expected that these buildings would have been further to the left of the graph outperforming the benchmark similar to FSC. However, they are all, for the most part, on par with the benchmark. We can also see from the graph that both the MATH and GEOG buildings are amongst the best performing buildings, even though they are 88 years old. These two buildings provide evidence that renovating a building proves to be a good technique to reduce environmental impacts. This can be explained by considering the lower impact of keeping much of the original materials in the building renovation projects.

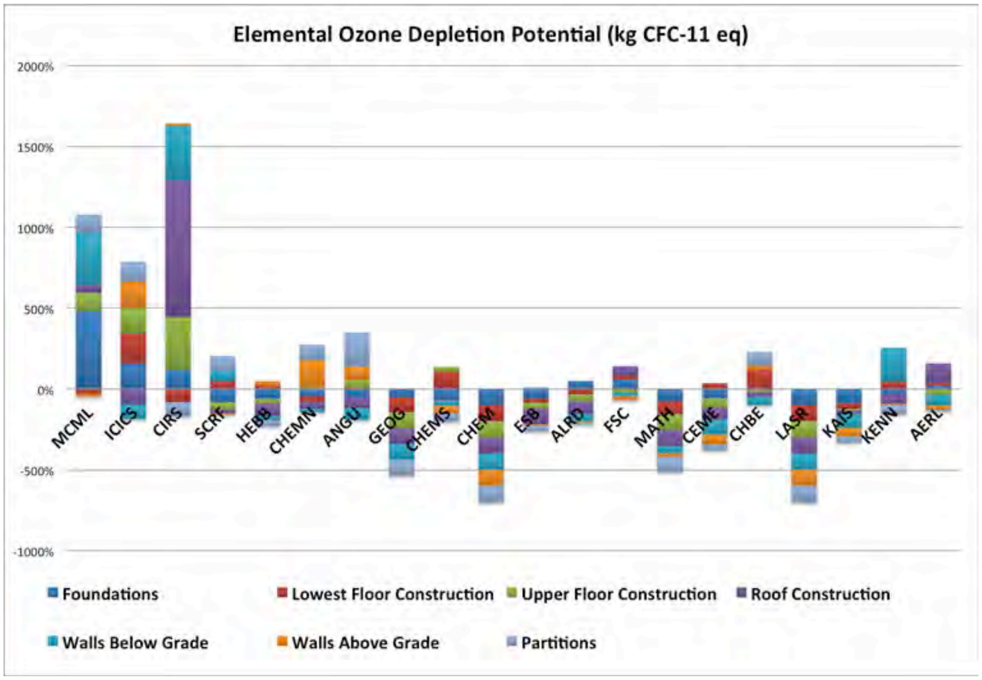
Hotspots

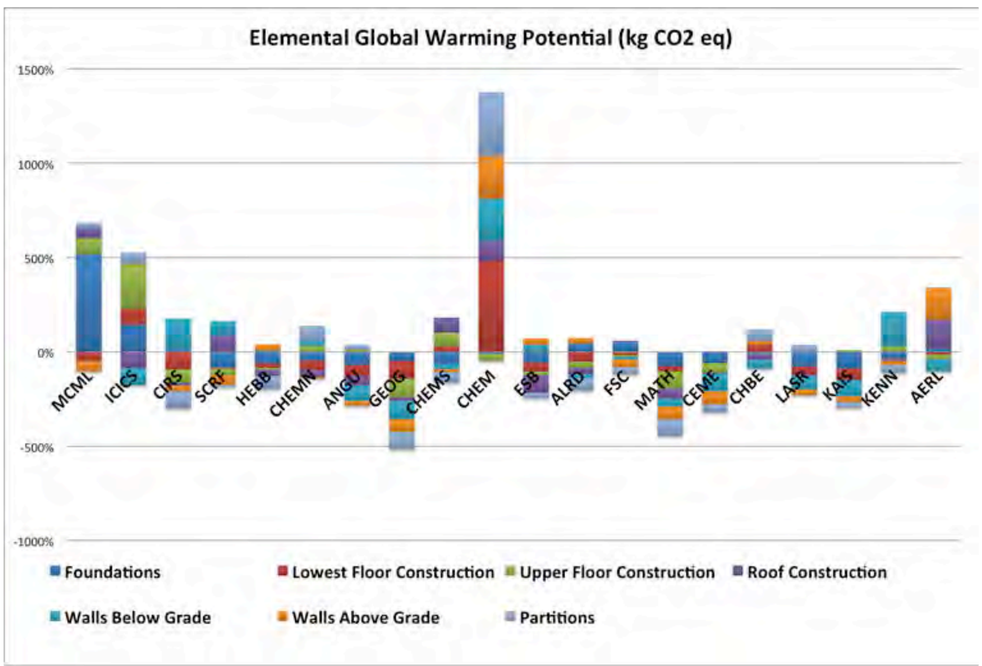
The major hotspots found are concentrated in three specific buildings: MCML, ICICS, and CHEM. In almost every impact category, these three buildings are performing the worst with respect to the benchmark. Looking through Figure 4 a-f, it is clear that these three buildings performed the worst in the majority of the impact categories with respect to the benchmark of the specified impact category. The only exception in these graphs is the performance of the CHEM building on Ozone depletion potential, where it performed the best; tied with the LASR building.

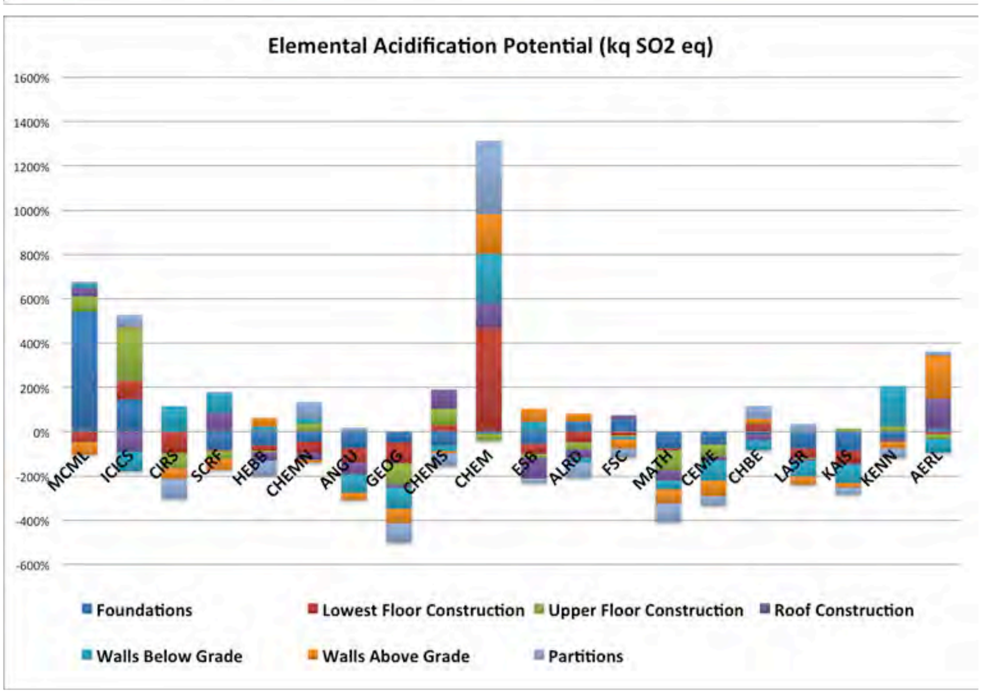
Beginning with MCML, the graphs in Figure 4 show, consistently, that the foundation of the building has the largest potential impact across all of the impact categories. From the database, the Bill of Materials for the foundation include concrete as the most significant material used. In fact, it is the most significant material used throughout the building when we look at the Bill of Materials for each element. From the data, the concrete also appears to be the major cause of eutrophication in the walls below grade.

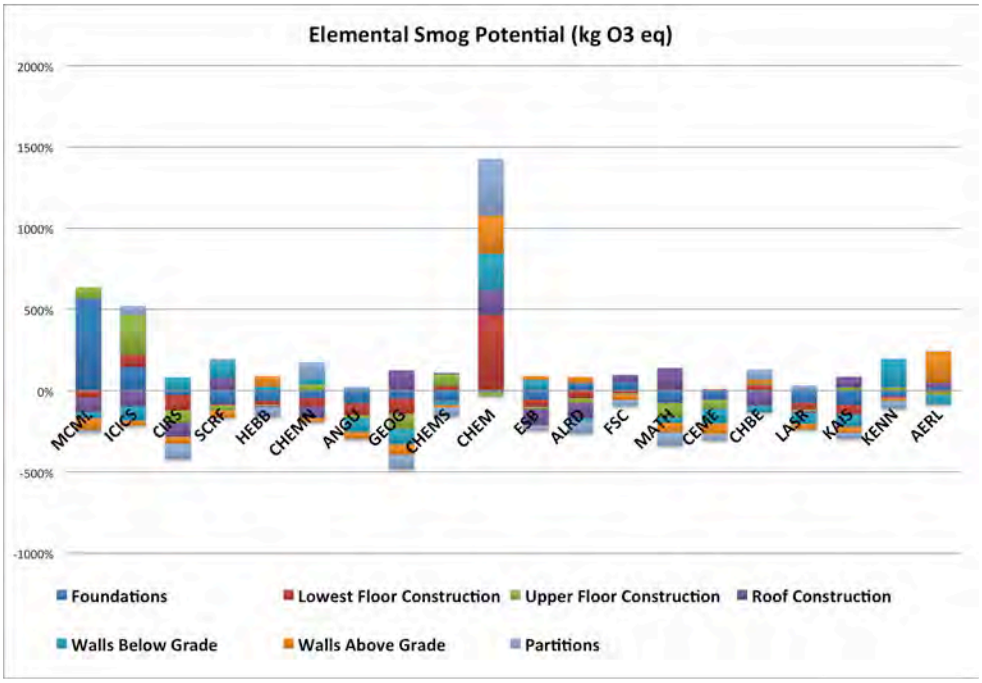
Figure 4 a-f - Impact categories

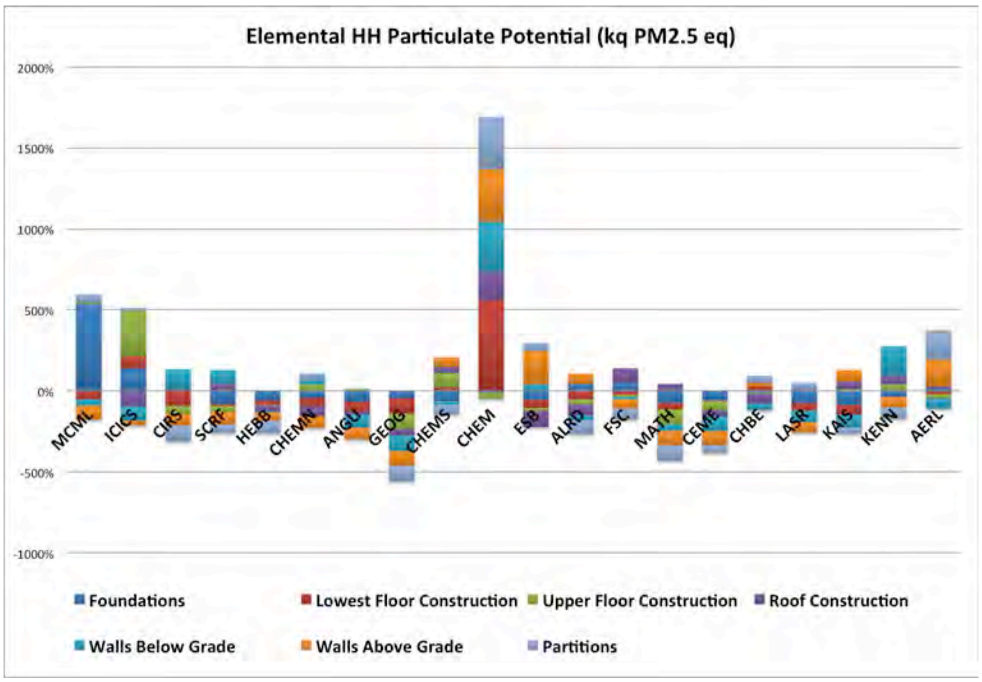



Elemental Ozone Depletion Potential (kg CFC-11 eq)
2000%
1500%
1000%
500%
0%
-500%
-1000%
MCML
ICICS
CIRS
SCRF
HEBB
CHEMN
ANGU
GEOG
CHEMS
CHEM
ESB
ALRD
FSC
MATH
CEME
CHBE
LASR
KAIS
KENN
AERL
Foundations
Lowest Floor Construction
Upper Floor Construction
Roof Construction
Walls Below Grade
Walls Above Grade
Partitions


Elemental Global Warming Potential (kg CO2 eq)
1500%
1000%
500%
0%
-500%
-1000%
MCML
ICICS
CIRS
SCRF
HEBB
CHEMN
ANGU
GEOG
CHEMS
CHEM
ESB
ALRD
FSC
MATH
CEME
CHBE
LASR
KAIS
KENN
AERL
Foundations
Lowest Floor Construction
Upper Floor Construction
Roof Construction
Walls Below Grade
Walls Above Grade
Partitions


Elemental Acidification Potential (kq SO2 eq)
1600%
1400%
1200%
1000%
800%
600%
400%
200%
0%
-200%
-400%
-600%
MCML
ICICS
CIRS
SCRF
HEBB
CHEMN
ANGU
GEOG
CHEMS
CHEM
ESB
ALRD
FSC
MATH
CEME
CHBE
LASR
KAIS
KENN
AERL
Foundations
Lowest Floor Construction
Upper Floor Construction
Roof Construction
Walls Below Grade
Walls Above Grade
Partitions





The ICICS building has similar results in upper floor construction and in its foundation. This again, is a result of using concrete in large amounts. In contrast, the walls below grade of ICICS outperforms the benchmark because the amount of concrete used is insignificant. This is also true for the roofing of the building as no concrete was used in the roofing material.

Finally, the CHEM building had the worst performance with respect to the benchmark Concrete was also here one of the materials used throughout the building. However, in addition to concrete, mortar and ballast were of importance as contributing factors (see figure 5 a-d). Figure 5 shows the materials used in 4 of the 7 elements of the CHEM building. The 4 elements included are the ones with mortar and ballast added to the Bill of Materials in addition to the concrete with the percent composition of the materials in those elements.

Note that there were different types of concrete in the Bill of Materials such as block concrete. However, they were reconciled to concrete in the figures for simplicity in order to show the overall composition of concrete irrespective of form or function.

From the composition of mortar and ballast, we can see that in 2 of the cases (walls above grade and partitions), the combination of mortar and ballast are in a larger composition. From the data of elemental impact assessment and the composition of materials, we can conclude that mortar and ballast have significant consequences on potential environmental impacts. While we cannot speculate on the type of mortar used, lime mortar reduces potential environmental impacts by 37.5% relative to concrete mortar[10]. To counteract the effects of ballast, a hybrid mixture such as glascrete (mixture of glass and concrete) can be used to reduce potential impacts[11]. Interestingly, CHEM performs the best against the benchmark in Ozone depletion potential. It may be that the addition of mortar and ballast improves the performance of the building in this respect as there is no other clear evidence in the database to indicate otherwise.

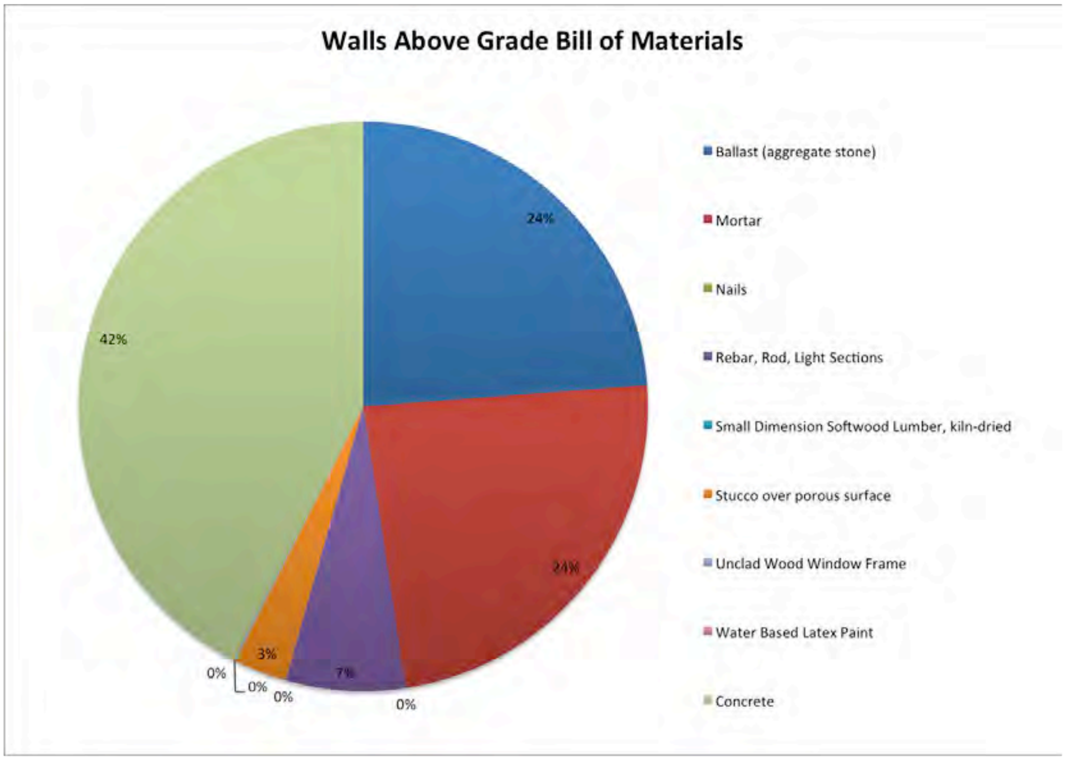
Quality of Data

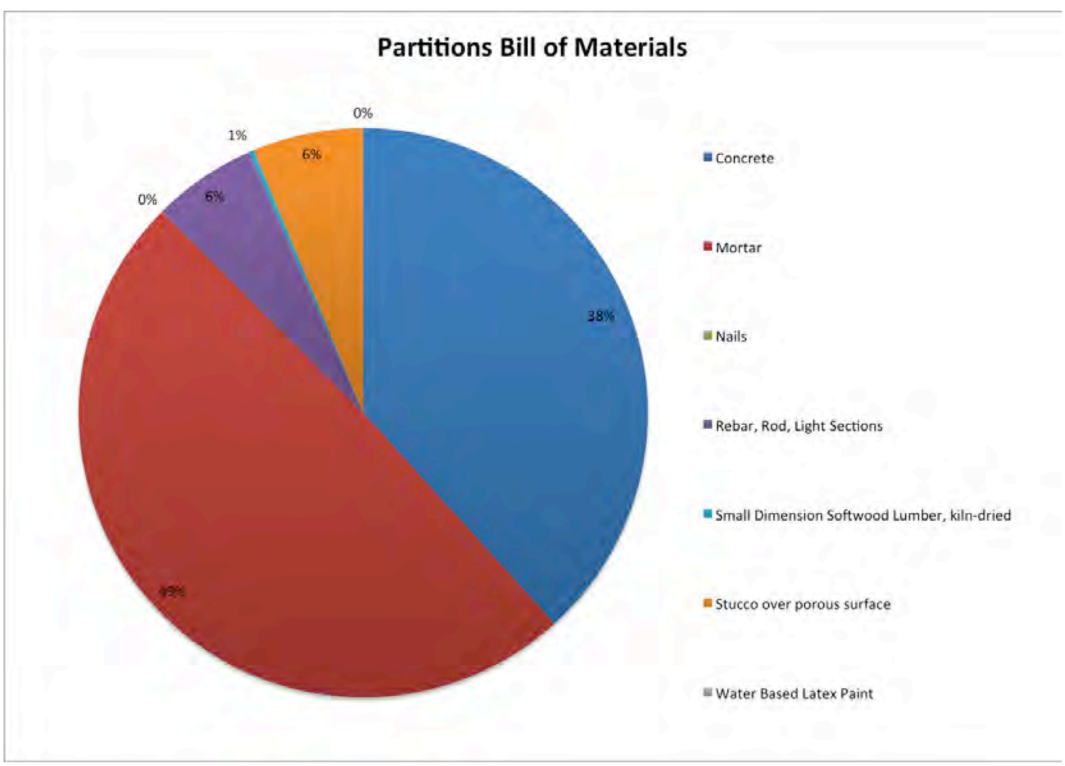
The database used in the development of the analysis included certain assumption as well as errors. The most prominent assumption made was the life expectancy of 60 years for the buildings when the data was processed through the Athena Impact Estimator. This assumption, although made standard for all buildings, may impact the final results. This is especially true since buildings such as MATH, GEOG, and CHEM are all 88 years old.

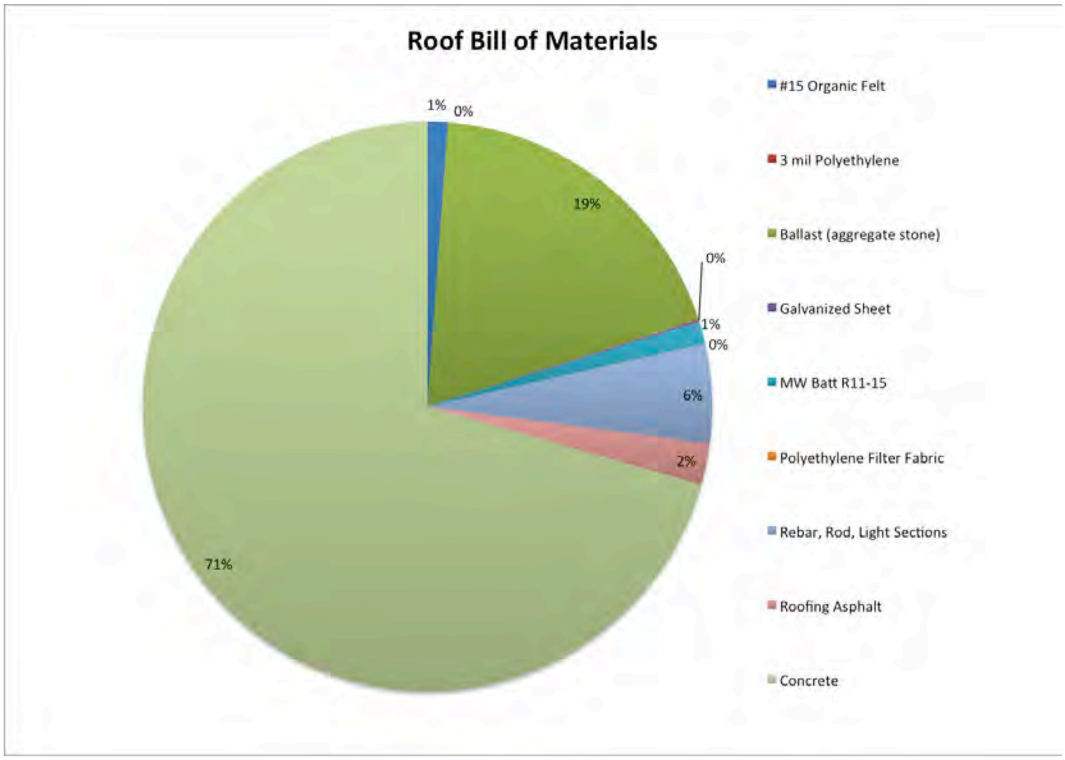
The errors in the database were in some cases random while in other cases caused by assumptions made through the Impact Estimator. Additionally, the data for certain buildings was not complete, such as the MUSC building where the data for the floor area was missing from the

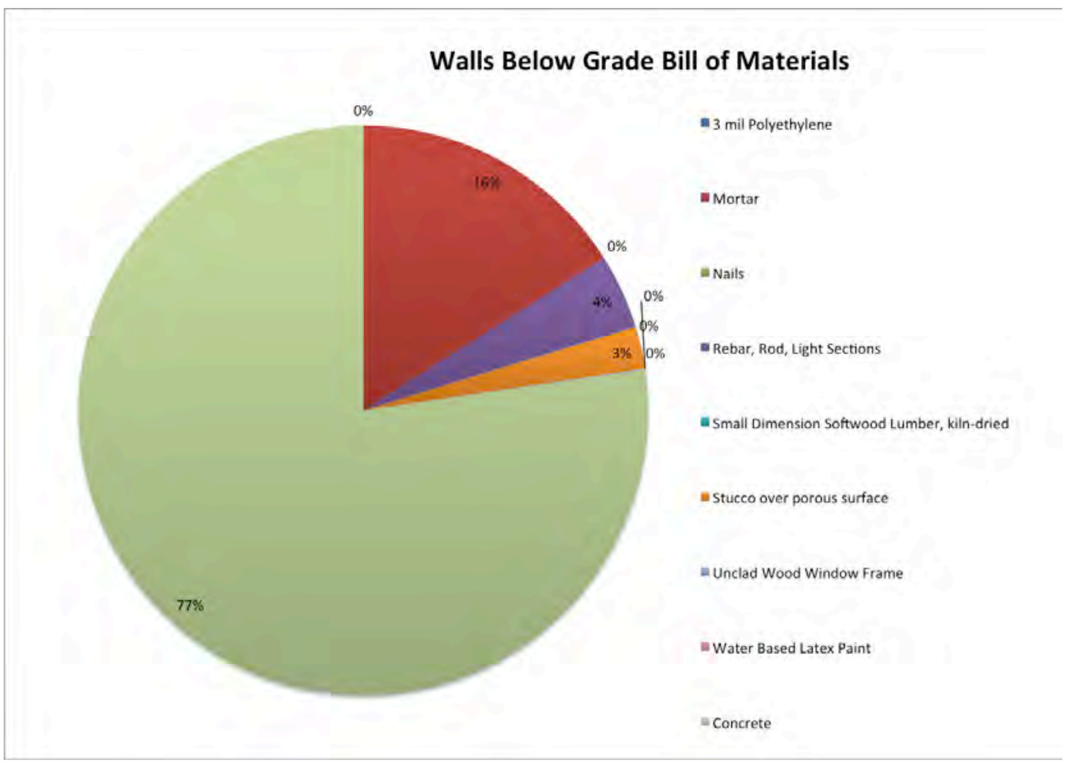
10. US Heritage Group. (2011). A Sustainable and Healthy Environment: Promoting Hemp and Lime Construction.
11. Concrete aggregate alternatives. (2013). Retrieved November 18, 2014, from http://www.appropedia.org/Concrete_aggregate_alternatives

Figure 5 a-d - Bill of materials for baseline building elements.






Roof Bill of Materials
#15 Organic Felt
3 mil Polyethylene
Ballast (aggregate stone)
Galvanized Sheet
MW Batt R11-15
Polyethylene Filter Fabric
Rebar, Rod, Light Sections
Roofing Asphalt
Concrete
1%
0%
19%
0%
1%
0%
6%
2%
71%


Walls Below Grade Bill of Materials
3 mil Polyethylene
Mortar
Nails
Rebar, Rod, Light Sections
Small Dimension Softwood Lumber, kiln-dried
Stucco over porous surface
Unclad Wood Window Frame
Water Based Latex Paint
Concrete
0%
16%
0%
4%
0%
0%
3%
0%
77%

database. To counteract this, this building was not used at all in the analysis. The assumptions made by the Impact Estimator may have led to other errors such as the technologies used to make the same product. The technologies used for producing the materials in the studied buildings might be non-conventional and not the same as the ones Impact Estimator assumes. For example, the technologies known by the database in the Impact Estimator might not be up-to-date with the newer buildings built at UBC (i.e. PHRM) or the much older ones (i.e. CHEM).

Another important point to mention is the interpretation of impact over time. During the construction of certain buildings, different impacts were regarded as a priority to prevent. For example, in the past, ozone depletion was a major concern whereas today, the ozone has recovered. While today, greenhouse gases are a major concern and is at the forefront of building design; this is another way the Impact Estimator is influenced.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Next Steps for Institutionalizing LCA at UBC

LCA Communication and Education Resources

One of the most important parts in institutionalizing LCA at UBC is to make the knowledge accessible and understandable to everyone.

UBC, according to the Climate Action Plan, has set its goal of reducing Greenhouse Gas emissions at Vancouver Campus with 33 percent by 2015, 67 percent by 2020, and 100 percent by 2050 (based on 2007 as the benchmark). According to the Climate Action Commitment, UBC is working towards becoming a net positive producer by 2050 - "We will go beyond carbon neutral through aggressive conservation, deployment of renewable technologies, and by re-designing how we conduct our business".[12]

Ambitious goals are a good way to promote progress and LCA should be included in this progress.

There is a long way to go before LCA is fully institutionalized at UBC. As of now, there is some analysis implemented into the LEED certification of new and renewal of existing buildings. By incorporating LCA in LEED, we can get a clearer view of what to design when constructing new buildings, renew old ones, and gathering knowledge of what the limitations of a buildings performance may be. It is possible for a building to be an energy neutral building or even an energy positive building. With Life Cycle Analysis and Life Cycle Costing, it will be easier to compare two quite different alternatives and see how they perform. This comparison will also identify costs associated with the operation of these buildings.

LCA should be included in courses at UBC so that students will be engaged in the development of this technique. It is important that students from different areas of study are allowed into this work, so that different perspectives are identified. It is not only for the university's advantage, but also for the students. By including the students into real life, ongoing projects, they are being exposed to the complexity of conducting an LCA and will gain knowledge and experience in a more extensive way than regular classroom lectures can. Students could be asked to conduct LCA of existing or

12. "University of British Columbia. (2010). Climate Action Plan. Retrieved from http://sustain.ubc.ca/sites/sustain.ubc.ca/files/uploads/CampusSustainability/CS_PDFs/PlansReports/Plans/UBCClimateActionPlan.pdf#

future buildings to evaluate the potential in performance of these buildings. These assignments can work as basis for a building designer, whose job is to develop a more comprehensive analysis.

LCA makes it possible to compare the environmental impact of products with similar properties and performance, so that a third party can pick their preferable product based on individual consideration. Right now, with the attention around the issues of global warming, it is well and good to know how a product performs with respect to environmental impacts and energy use. However, if we do not have a proper basis to compare our results with, a suitable alternative will not be identified. UBC should establish an open source initiative with other universities in Canada to systemize information about campus building performances. Benchmarks will naturally vary due to variables such as expected lifetime, method of construction, ground conditions, but this can nonetheless be a solid basis for setting attainable, realistic goals.

In order to make LCA more widely available for students, more accessible software should be developed to perform LCA. For example, Harvard University has developed a Life Cycle Cost Calculator to aid decision makers when planning for constructing new buildings or renovating old ones[13]. At UBC, developing something connected to the "Pulse Building Dashboard" would be appropriate[14]. The dashboard could show LCA of every building and give you the ability to change the Life Cycle Inventory or construction method and see how emissions are changing. Additionally, the ability to change between different Life Cycle Impact Assessment methods to change the characterization factor can be incorporated. This way, the student can decide what kind of emissions to value and be given a result regarding to their considerations.

LCA Modeling Tools

UBC needs a set of systems to measure how their existing buildings are performing in order to determine the sustainability of these buildings and their impact on the environment. The University also needs to provide this information prior to projects being conducted in order to identify key design requirements for developing buildings with LCA in mind.

There are many different types of LCA tools that exists around the world. However, the differences between the different levels of these tools must first be identified.

13. Life Cycle Costing. (n.d.). Retrieved November 16, 2014, from http://green.harvard.edu/topics/green-buildings/life-cycle-costing
14. UBC Energy Dashboard (n.d.). Retrieved November 18, 2014, from https://my.pulseenergy.com/ubc/dashboard#/location/1317

“Level 1 tools focus on individual products or simple assemblies and are used to make comparisons in terms of environmental or economic criteria (or both), especially at the specification stage of project delivery. Level 1 tools can be further grouped into those into those intended to use for LCA practitioners (Level 1A) and those intended for those who simply want the results, with the detailed LCA work done in the background (Level 1B)

“Level 2 tools focus on the whole building, or on complete building assemblies or elements, with each tool typically providing decision support with regard to specific areas of concern, such as operating energy, lighting, life cycle costing, and life cycle environmental effects. These tools tend to be data-oriented and objective, and apply from the early conceptual through detailed design stages. Again, the emphasis here is on the LCA tools.”

“Level 3 tools are the more familiar whole building assessment frameworks or systems that encompass a broader range of environmental, economic, and social concerns relevant to sustainability. They use a mix of objective and subjective inputs, leaning on level 2 tools for much of the objective data-energy simulation results, for example. All use subjective scoring or weighting systems to distill the information and provide overall measures, and all can be used to inform or guide the design process. Only those that explicitly incorporate LCA are considered here.”[15]

Table 1 - LCA Tools[16]

	Country	Comments
Level 1A Tools		
SimaPro	Netherlands	While the countries of origin vary, these tools can be used in different regions by selecting or incorporating the appropriate data. But the task is best done by LCA practitioners for whom the tools are intended.
GaBi	Germany	
Umberto	Germany	
TEAM	France	
Level 1B Tools		
BEES	USA	Combines LCA and life cycle costing. Includes both brand-specific and generic data.
LCAiT	Sweden	Streamlined LCA tool for product designers and manufacturers.
TAKE-LCA	Finland	LCA tool for comparison of HVAD products, including energy content of the product and energy consumption.

15. Trusty, W., & Horst, S. (2005). LCA Tools Around the World. In Life Cycle Assessment and Sustainability - A Supplement to Building Design & Construction (p. 12). Green Building Movement.
16. Trusty, W., & Horst, S. (2005). LCA Tools Around the World. In Life Cycle Assessment and Sustainability - A Supplement to Building Design & Construction (p. 13). Green Building Movement.

	Country	Comments
Level 2 Tools		
Athena Environmental Impact Estimator (EIE)	Canada/USA	All of these tools use data and incorporate building systems that are specific to the country or regions for which they were designed.
BRI LCA (energy and CO2)	Japan	
EcoQuantum	Netherlands	
Envest	United Kingdom	
Green Guide to Specifications	United Kingdom	
LISA	Australia	
LCADesign (under development)	Australia	
Level 3 Tools		
BREEAM	United Kingdom	Uses LCA results from the Level 2 Green Guide.
BGTool	International	Experimental platform that accepts LCA results or performs a rudimentary LCA calculation using built-in calculators.
Green Globes	Canada/USA	Assigns a high percentage of resource use credits based on evidence that a design team has conducted LCA using a recognized Level 1 or 2 tool.

LCA Databases

Some LCI Databases include:

- Athena LCI Database
- US LCI
- ELCD
- EcoInvent
- GaBi

A major weakness with today's databases is the lack of accurate EPDs. This makes it difficult to conduct accurate analysis without having a large basis to base your analysis upon. The lack of EPDs is a result of companies and suppliers not seeing the value of spending time to develop environmental impact information about their products.

UBC can influence the construction industry to provide better EDPs by collaborating with other educational institutions in creating awareness about this. To push construction companies in the development of EPDs, incentives should be provided to show them the value of the information. An incentive could be to make it a necessity to have a well-developed EPD database in order to receive contracts to construct buildings on campus. This could help manufacturers in understanding the advantages of creating EPDs.

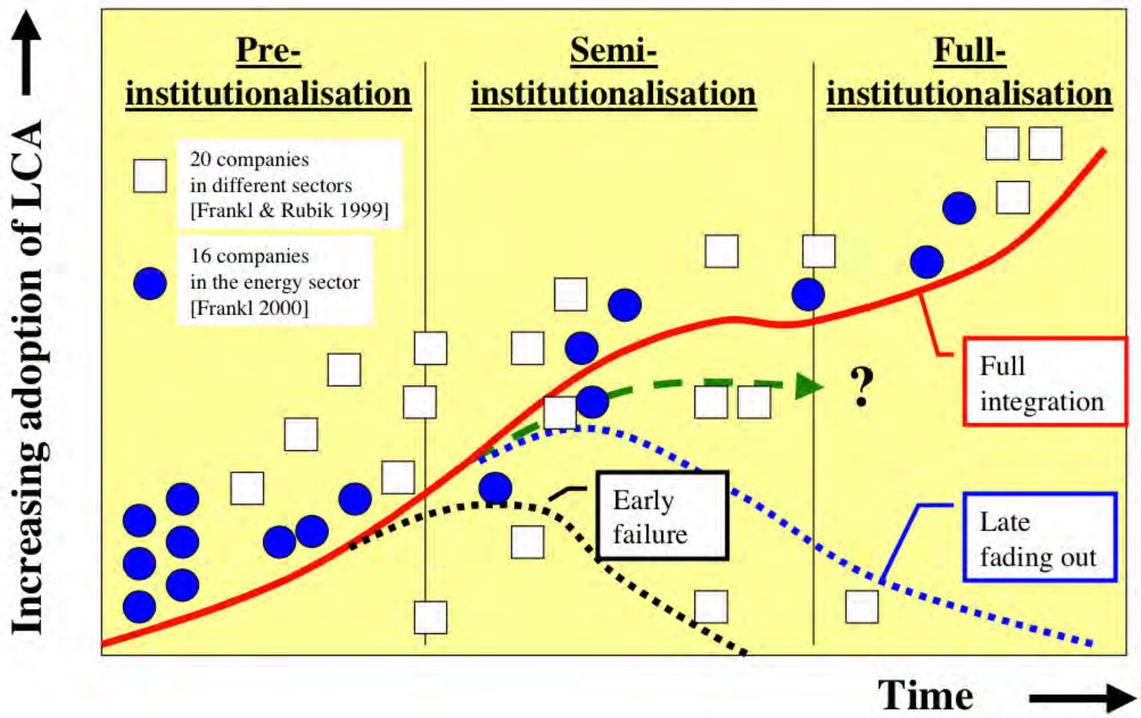
LCA Decision Making Methods

LCA is currently in-between pre-institutionalization and semi-institutionalization. The tool is being applied within specific areas by practitioners. At UBC, LCA is being used only in in a few building projects.

There are a few factors linked to the institutionalizing of LCA in order to make it successful. Some state that there are no success factors needed in the first stage in institutionalizing, but for the second stage in institutionalizing, the involvement of top-management becomes an important aspect to continue on further development[17]. Since the development is based on a bottom-up strategy, it is necessary to prioritize involvement and motivation in practitioners, as they are the ones actually using the LCA tools. Their participation becomes more and more important throughout the different stages as more stakeholders will be involved in institutionalizing LCA.

17. Frankl, P. (2001). Life cycle assessment as a management tool. Fontainebleau: INSEAD.

Figure 7 - LCA institutionalizing phases.[17]



However, the most important success factor, according to Frankl, is that there is an "entrepreneur" or "champion" to push the development further within the organization. "It is him who elaborates the strategy to demonstrate the importance of LCA and create consensus around it." UBC needs one or more champions for institutionalizing LCA.

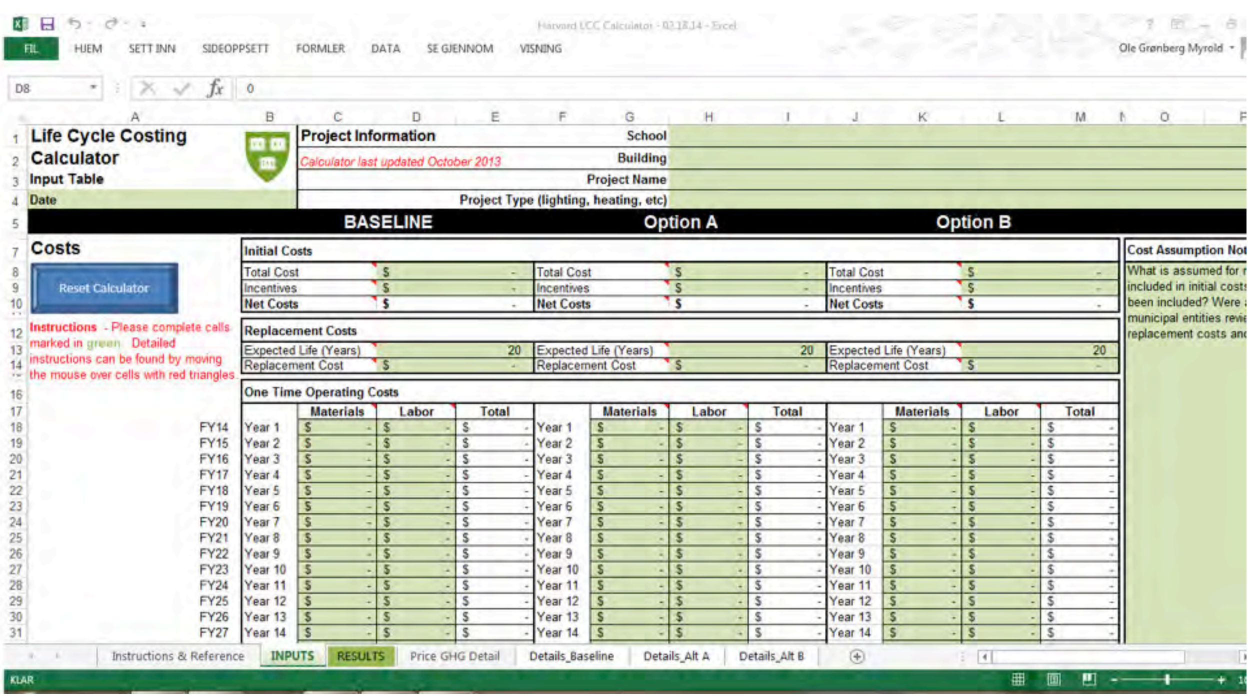
Internally in an organization, it is necessary to establish knowledge on the method and application of LCA. Frankl mentions that no organization have relied on external support. Organizations need to have an environmental policy so that they are motivated to use the tool for what it is worth.

The role of LCA changes over time with respect to institutionalization. In the beginning, it is mostly for educational purposes with a retrospective focus. Through the mid-institutionalize stage there is a change in perspective, where LCA is used to design and develop new products rather than confirm already known information from the past. When entering full-institutionalization LCA becomes a quasi-routine tool. The learning value becomes much lower than in earlier stages.

If UBC is going to complete the step of semi-institutionalization LCA, it is reasonable to say that they need to have LCA acknowledged by top-management within two years and have given specific tasks to main promoters. This project should contain a plan of how buildings at UBC are going to be assessed according to LCA and how Life Cycle Impact Assessments should be applied. Results from all analysis should be incorporated in a database of the campus buildings at UBC, giving an overview of how the campus buildings perform with respect to environmental impacts during all building stages. Within five years, there should be a solid database of how buildings perform at campuses around Canada, providing the institutions with a wide view of the benchmarks of campus buildings. This way there can be developed estimates of what is possible regarding building construction in the future, giving decision makers a highly informative basis to base their decisions on. As this information is being shared across the country, it is necessary that information is being evaluated critically and retrieved through systematic scientific analysis.

UBC can benefit from looking at a LCC tool developed at Harvard University, as seen in Figure 8. This Excel sheet provide an easy overview of a comparison of multiple alternative solutions, making it a good tool for preliminary economic analysis. UBC should learn from this tool when making their own LCA tools for decision making. If UBC is going to institutionalize the use of LCA, specific guidelines of how the process is being conducted needs to be set. It is of great importance that every analysis is conducted based on the same basis, evaluating with respect to the same environmental impacts.

Figure 8 - Harvard LCC tool.[18]



18. Life Cycle Costing. (n.d.). Retrieved November 18, 2014, from http://green.harvard.edu/topics/green-buildings/life-cycle-costing

Conclusion

Up until now, LCA has been used at a very limited degree at UBC. While there has been some LCA studies performed on some projects, such as the UBC District Energy Centre new building project and the Buchanan Building D renovation, LCA is still not being used at its full potential. Part of the reason why LCA is not widely used at UBC comes down to the lack of inclusion of LCA in the UBC sustainability programs.

Of the four major UBC sustainability programs discussed, only one of them mentioned the LCA technique. The UBC RFI response evaluation criteria mention that developing a life cycle assessment of project options and their costs is a key part of many RFI responses. Other sustainability programs at UBC should follow the RFI response evaluation criteria by not only incorporating LCA-esque techniques, but actually specifically mention Life Cycle Analysis as a key part of the design process for new building projects and renovation projects at UBC.

In the LCA analysis of 24 academic buildings at UBC, an environmental impact baseline average was developed and individual buildings were compared to it. Three buildings, Chemistry, Macmillan, and ICICS all stood out as the three worst-performing buildings overall. The Chemistry building's overall environmental impact was found to be 900% above the baseline. Looking further into these three buildings, it was found that concrete appears to be the largest contributor to the high environmental impact.

Some problems were also identified with the LCA analysis dataset itself. As a result of this, some buildings were excluded from the dataset because of missing or poor quality data.

Of the buildings with low environmental impacts compared to the baseline, it was found that renovations are a key marker for low environmental impact. Significant amounts of energy, resource and pollution are embodied within the existing building, as most environmental impacts are a result of the manufacturing of the building materials and the construction of the building. Large amounts of waste, water pollution and resource-use are avoided by retaining and reusing materials.

Finally, in the section discussing the next steps in institutionalizing LCA at UBC, it was found that there are two main aspects to be considered for a wider adoption of LCA:

1. UBC needs to establish their goals with LCA. As LCA has entered the semi-institutionalized stage, it is necessary to create a long term strategy to fully address the future of LCA at UBC. Clear UBC guidelines for Goal and Scope of an LCA should be created so that all future analysis is based on the same basis, and within the same boundaries. Furthermore, a database of information on campus building performance should be developed and shared within the broader educational community to promote progression within the LCA subject.
2. LCA should be made more accessible for the broader UBC community. There could be simplified LCA tools developed to aid students' understanding of the process, and provide students with a more hands-on experience without needing to know all the theory behind it.

Overall, UBC is in a unique position to embrace the LCA technique in both new building projects and in renovated building projects. This would not only help UBC get closer to achieving its bold sustainability goals, but also help further institutionalize LCA amongst the broader building design community.

Author Reflection - Sirous Soltanolketabi

Prior to this course, I had very little knowledge of LCA and it's methodologies. We touched on it briefly in a course I took in the Materials Engineering Department at UBC, however, not to the depth of which we discussed LCA in this course. For example, the different software and databases that are available and being worked were completely new to me and fascinating. At the same time, I thought LCA was a lot further developed than it currently is. It seems that LCA is still in the growing stages with a lot of work left to remove a lot of the inconsistencies it currently has. The biggest task and a continuous one, is that of the development of databases. These need to be improved and updated more frequently especially in a technology driven society that we live in. I'm really interested in seeing how LCA expands globally and how flexible it is relative to cultures and different environments people live in.

What interested me most about this course is the realistic nature with which LCA is conducted. It is not based on recycling for the sake of recycling. Rather, I learned that LCA is much more than just rhetoric, quantifiable data can be derived from the materials we use in design to identify environmental impacts. The greatest thing I learned about LCA is that it can be a great decision maker for projects in the design phase. Whether determining which materials to use or which process would work best, LCA can help identify the most environmentally friendly way with data to back it up.

Graduate Attribute Name	Description	Select the content code most appropriate for each attribute from the dropdown menu	Comments on which of the CEAB graduate attributes you believe were addressed during your class experience. Reflect on the experiences you got from the games, lectures, assignments, quizzes, guest speakers organized for the class, and your final project experience.
1 Knowledge Base	Demonstrated competence in university level mathematics, natural sciences, engineering fundamentals, and specialized engineering knowledge appropriate to the program.	IA = introduced & applied	Fundamentals of engineering were applied in this course, I thought it was very similar to work done in engineering companies. I had similar experience in my co-op positions in analysing data and reporting the results. I thought this course is a great segway to the real world of engineering.
2 Problem Analysis	An ability to use appropriate knowledge and skills to identify, formulate, analyze, and solve complex engineering problems in order to reach substantiated conclusions.	ID = introduced & developed	I thought more time could have been spent on learning the fundamentals of LCA more in depth. It seemed like we moved very quickly early on and a lot of the material didn't sink in until near the end of the course.
3 Investigation	An ability to conduct investigations of complex problems by methods that include appropriate experiments, analysis and interpretation of data, and synthesis of information in order to reach valid conclusions.	A = applied	I thought investigation was well established in this course and implemented any time it was possible. All of our assignments required this from us.
4 Design	An ability to design solutions for complex, open-ended engineering problems and to design systems, components or processes that meet specified needs with appropriate attention to health and safety risks, applicable standards, and economic, environmental, cultural and societal considerations.	ID = introduced & developed	I think more time could have been spent on this portion of the course. The design seems to relate directly to Athena Impact Estimator and tools of similar nature. More time is needed to have a better understanding of the tool and how to manipulate it in order to achieve desired results.
5 Use fo Engineering Tools	An ability to create, select, apply, adapt, and extend appropriate techniques, resources, and modern engineering tools to a range of engineering activities, from simple to complex, with an understanding of the associated limitations.	IDA = introduced, developed & applied	The 2 main tools used in this course was the Impact Estimator and Excel. The latter I thought was used more so and the most intuitive. Again, more time was needed to spent on the Impact Estimator.
6 Individual and Team Work	An ability to work effectively as a member and leader in teams, preferably in a multi-disciplinary setting.	IDA = introduced, developed & applied	The groups I was in was diverse and we came from different engineering background. Although 2 of us were in the IGEN program, our engineering focuses were completely different. Communication was clear and tasks were completed on time.

7 Communication	An ability to communicate complex engineering concepts within the profession and with society at large. Such ability includes reading, writing, speaking and listening, and the ability to comprehend and write effective reports and design documentation, and to give and effectively respond to clear instructions.	ID = introduced & developed	I thought communication coule be developed further. Not all instructions were very clear on tasks, it seemed to be disorganised. Once we figured out what was required from us, the tasks were quite simple. I think an emphasis should be put on what we're trying to find instead of giving students a step by step procedure of how to find something without knowing what the end goal is. We can figure it out if we know what we're looking for.
8 Professionalism	An understanding of the roles and responsibilities of the professional engineer in society, especially the primary role of protection of the public and the public interest.	N/A = not applicable	I didn't find this to have been addressed in the course, the only case being that of protecting the public and in the case of LCA, that would mainly be their health.
9 Impact of Engineering on Society and the Environment	An ability to analyze social and environmental aspects of engineering activities. Such ability includes an understanding of the interactions that engineering has with the economic, social, health, safety, legal, and cultural aspects of society, the uncertainties in the prediction of such interactions; and the concepts of sustainable design and development and environmental stewardship.	IDA = introduced, developed & applied	I thought that this was addressed throughout the course and emphasised as part of LCA.
10 Ethics and Equity	An ability to apply professional ethics, accountability, and equity.	A = applied	LCA is a scientific method and therefore is designed to be objective and have the best interests of humanity and the environment in mind.
11 Economics and Project Management	An ability to appropriately incorporate economics and business practices including project, risk, and change management into the practice of engineering and to understand their limitations.	D = developed	I think these ideas were introduced indirectly as part of engineering knowledge, but we did not directly apply them.
12 Life-long Learning	An ability to identify and to address their own educational needs in a changing world in ways sufficient to maintain their competence and to allow them to contribute to the advancement of knowledge.	A = applied	I'm not too sure what the decription means, but this course did set me up to think about my knowledge level about the topic. It is one of constant change since data interpretation will also change over time.

Author Reflection - Ole Grønberg Myrold

I have had a brief introduction to the methodology of LCA from previous courses at my university in Norway, but not studied the subject in such an extent as in CIVL498C. When I applied to the course I was a bit unsure of that to expect. I am really found of the idea to but a number to the emissions from a construction project in order to make comparable, and I have been really astonished about the complexity and extent of the whole assessment. It has been some interesting lectures when moving the focus from a narrow focus of performance to the broad view of a cradle to grave perspective. E.g. if paper bags make a less environmental impact than plastic bags.

Though I feel that this class has a potential. It is really great and highly motivating that we get to do assignments which will be used in the further development of the course and Green Buildings at UBC. But as most of the lectures consists of approximately three hours of Power Point slides and lecturing it can be a bit monotonous after a while. I feel that the course would have been easier to structure if the lectures was divided over two days with one and a half hour on each day. This is only small issues, but in some lectures it feels that there is not enough content to fill up three hours. One thing that is more important and which is easy to improve is to try and link the different subjects, which is lectured, up to the different part of the LCA structure. I felt that it some times was difficult to know where the information being lectured should be applied. That we learned about many small fractions of LCA, besides the main part, which was difficult to place in the big picture. Of course this can be a result of much new information over a short period, but if every subject could be linked to one specific model, then I think the students outcome would benefit from this.

CIVL498C together with other courses I am taking at UBC has given me a better perspective of the possibility and necessity to treat limited resources in an efficient way. With a background in Civil Engineering this have made me interesting in the subject of recycling and reuse of construction materials and feel that this could be an appropriate subject for a masters thesis. I have enjoyed to learn about the value of LCA as a measuring tool, and regarding to the emerging wave of BREEAM buildings in Norway this will be really useful for me in the future.

Graduate Attribute Name	Description	Select the content code most appropriate for each attribute from the dropdown menu	Comments on which of the CEAB graduate attributes you believe were addressed during your class experience. Reflect on the experiences you got from the games, lectures, assignments, quizzes, guest speakers organized for the class, and your final project experience.
1 Knowledge Base	Demonstrated competence in university level mathematics, natural sciences, engineering fundamentals, and specialized engineering knowledge appropriate to the program.	IDA = introduced, developed & applied	Introduced through lectures, developed with assignments and applied in quizes and final project
2 Problem Analysis	An ability to use appropriate knowledge and skills to identify, formulate, analyze, and solve complex engineering problems in order to reach substantiated conclusions.	IDA = introduced, developed & applied	Look at the whole life time of a product or a process will give you a quite different view than for a specific stage or part of its life time. Gradle-to-grave needs to be analysed in order to evaluted the total impact of your product.
3 Investigation	An ability to conduct investigations of complex problems by methods that include appropriate experiments, analysis and interpretation of data, and synthesis of information in order to reach valid conclusions.	IDA = introduced, developed & applied	By conducting LCA of campus buildings at UBC.
4 Design	An ability to design solutions for complex, open-ended engineering problems and to design systems, components or processes that meet specified needs with appropriate attention to health and safety risks, applicable standards, and economic, environmental, cultural and societal considerations.	IA = introduced & applied	Change design of building
5 Use fo Engineering Tools	An ability to create, select, apply, adapt, and extend appropriate techniques, resources, and modern engineering tools to a range of engineering activities, from simple to complex, with an understanding of the associated limitations.	IA = introduced & applied	Athena Impact Estimator
6 Individual and Team Work	An ability to work effectively as a member and leader in teams, preferably in a multi-disciplinary setting.	A = applied	Induvidual with early stages of the course and developed into group work for the final report

7 Communication	An ability to communicate complex engineering concepts within the profession and with society at large. Such ability includes reading, writing, speaking and listening, and the ability to comprehend and write effective reports and design documentation, and to give and effectively respond to clear instructions.	IDA = introduced, developed & applied	We were given the methodology in class and applied the knowledge in the project and different assignments.
8 Professionalism	An understanding of the roles and responsibilities of the professional engineer in society, especially the primary role of protection of the public and the public interest.		
9 Impact of Engineering on Society and the Environment	An ability to analyze social and environmental aspects of engineering activities. Such ability includes an understanding of the interactions that engineering has with the economic, social, health, safety, legal, and cultural aspects of society, the uncertainties in the prediction of such interactions; and the concepts of sustainable design and development and environmental stewardship.	I = introduced	As LCA is a tool to measure environmental impact of a product, we have been introduced to this. However, other aspects like economical, social, legal or cultural have not been included.
10 Ethics and Equity	An ability to apply professional ethics, accountability, and equity.		
11 Economics and Project Management	An ability to appropriately incorporate economics and business practices including project, risk, and change management into the practice of engineering and to understand their limitations.		
12 Life-long Learning	An ability to identify and to address their own educational needs in a changing world in ways sufficient to maintain their competence and to allow them to contribute to the advancement of knowledge.	I = introduced	Shown how LCA can be used as a tool to measure building performance against each other. Introduced to how characterization may change over time, e.g. reducing Ozon Layer was an important issue earlier.

Author Reflection - Kristoffer Vik Hansen

I have been interested in sustainability for many years. As a matter of fact, I first started learning more about sustainable practises at the Norwegian University of Science and Technology in 2009. Two of my courses - Innovation and Sustainable Solutions - introduced me to different perspectives in sustainability.

In the Innovation course, me and a group of four other students interviewed a number of different companies, from a oil drilling company to the Norwegian postal service, about their sustainable practices. TINE, the largest Norwegian dairy company, used the report my group created to explore ways for them to improve their internal sustainability efforts.

Sustainable Solutions, on the other hand, was a research-driven course where I looked at the status and potential of European offshore wind energy. The 20-page report I created on the subject really sparked my interest for renewable energy sources, and showed that there is a large potential for offshore wind energy, especially in Northern Europe.

However, it was not until May 2013 and a Co-op job at FVB Energy Inc, a district energy consultant, that I was more formally introduced to sustainable engineering principles. The company culture at FVB is inherently geared towards sustainable principles, which is an inspiringly different culture compared to many traditional engineering companies. In this job we worked worked with LEED principles daily, and it was through this work I got a taste for what LCA is.

Throughout this CIVL 498C course we covered the four main phases of LCA - Goal and Scope, Inventory Analysis, Impact Assessment, and Interpretation.

To get more context around the subject, we were also introduced to the history of LCA, different LCA software tools, and emerging topics in LCA. Looking at LCA studies at UBC and learning about the local LCA efforts was very beneficial as it gave me a more tangible view on what LCA can and should be used for in the local community.

However, the most interesting topic I learned about in this course was the challenges LCA are facing. Working on a subject that is not fully institutionalized and developed was very different from what I have come to expect from my courses at UBC. Learning about topics such as manufacturers unwillingness to provide EPDs, the uncertainty in a lot of inventory data, and challenges in broadening LCA adoption therefore gave a nuanced perspective to the LCA discussion.

In the final project I found the academic building LCA analysis and the next steps in institutionalizing LCA particularly interesting. For the analysis, working on a dataset that is so close to our everyday lives (being at UBC), made this a lot more relevant and motivating. For the next steps in institutionalizing, it was very interesting to work on such an open-ended section, proposing possibly unconventional ways to make LCA more integrated into the future of UBC's building design processes.

My expectations starting this course was very different from how I now look back at it. Here are some of the things that differed from my expectations:

1. The scientific community around LCA. I did not expect LCA to be as scientific as I was expecting going into the course. Many other sustainability techniques are a lot less scientifically proven, being more about greenwashing than actual science.
2. The importance of LCA analysis. It was interesting to learn that seemingly sustainable acts, such as recycling, might not always be the solution with the least environmental impact.
3. The continued challenges LCA are facing. As previously mentioned, I did not expect to learn about the continued challenges LCA are facing. Proposing solutions to some of these challenges was especially interesting and motivating for my continued learning about the topic.

Graduate Attribute Name	Description	Select the content code most appropriate for each attribute from the dropdown menu	Comments on which of the CEAB graduate attributes you believe were addressed during your class experience. Reflect on the experiences you got from the games, lectures, assignments, quizzes, guest speakers organized for the class, and your final project experience.
1 Knowledge Base	Demonstrated competence in university level mathematics, natural sciences, engineering fundamentals, and specialized engineering knowledge appropriate to the program.	IDA = introduced, developed & applied	We were well introduced to the subject of LCA, developed our LCA skills through working on in-class assignments, and applied our knowledge by having a final project that required all the skills we acquired Also introduced engineering fundamentals in terms of being able to look critically at data.
2 Problem Analysis	An ability to use appropriate knowledge and skills to identify, formulate, analyze, and solve complex engineering problems in order to reach substantiated conclusions.	IA = introduced & applied	Worked with large datasets and extracting important information.
3 Investigation	An ability to conduct investigations of complex problems by methods that include appropriate experiments, analysis and interpretation of data, and synthesis of information in order to reach valid conclusions.	A = applied	Applied this primarily through our final project, were we investigated to what extent LCA is used at UBC, analysed a LCA dataset, and looked at the future for LCA at UBC.
4 Design	An ability to design solutions for complex, open-ended engineering problems and to design systems, components or processes that meet specified needs with appropriate attention to health and safety risks, applicable standards, and economic, environmental, cultural and societal considerations.	N/A = not applicable	Did not design solutions.
5 Use fo Engineering Tools	An ability to create, select, apply, adapt, and extend appropriate techniques, resources, and modern engineering tools to a range of engineering activities, from simple to complex, with an understanding of the associated limitations.	ID = introduced & developed	We were introduced to LCA tools such as SimaPro, Impact Estimator, and Revit (with LCA plugin) We were also able to develop our skills in working with the LCA tool Athena Impact Estimator, giving us some insight into how this tool works.
6 Individual and Team Work	An ability to work effectively as a member and leader in teams, preferably in a multi-disciplinary setting.	IDA = introduced, developed & applied	By working in a team for our final project we were able to hone our teamwork skills. We were also introduced to how engineering consulting works, and the importance of a multidisciplinary team in this setting.

7 Communication	An ability to communicate complex engineering concepts within the profession and with society at large. Such ability includes reading, writing, speaking and listening, and the ability to comprehend and write effective reports and design documentation, and to give and effectively respond to clear instructions.	A = applied	Created a final project were one of the requirements was to communicate the topic as efficiently as possible to stakeholders outside the engineerings field. Also got a chance to have class discussions on the different aspects of LCA. Our final presentation will also help us apply our knowledge and communicate the topics to a broader audience.
8 Professionalism	An understanding of the roles and responsibilities of the professional engineer in society, especially the primary role of protection of the public and the public interest.	IDA = introduced, developed & applied	Through learning about LCA I have gained an understanding of how much engineering can affect society. This applies especially to the environmental impact of engineering.
9 Impact of Engineering on Society and the Environment	An ability to analyze social and environmental aspects of engineering activities. Such ability includes an understanding of the interactions that engineering has with the economic, social, health, safety, legal, and cultural aspects of society, the uncertainties in the prediction of such interactions; and the concepts of sustainable design and development and environmental stewardship.	IDA = introduced, developed & applied	One of the fundamental aspects of this course! By learning about LCA we will have a better understanding on how engineering interacts with the health and safety aspects of society. I see this point as one of the biggest take-home messages I got from this class. Understanding the environmental implications of the built environment has been a great learning experience.
10 Ethics and Equity	An ability to apply professional ethics, accountability, and equity.	IA = introduced & applied	We were showed the importance of highlighting any uncertainties in our data. This will aid our understanding of exploring data in both positive and negative aspects, regardless of your subjective opinion.
11 Economics and Project Management	An ability to appropriately incorporate economics and business practices including project, risk, and change management into the practice of engineering and to understand their limitations.	I = introduced	We were introduced to the fundamentals of how engineering consulting works.
12 Life-long Learning	An ability to identify and to address their own educational needs in a changing world in ways sufficient to maintain their competence and to allow them to contribute to the advancement of knowledge.	IA = introduced & applied	Learned concepts on environmental apects of engineering that will have large value for our society as we og forward.