LIFE CYCLE ASSE

LIFE CYCLE ASSESSMENT

Centre for Interactive Research on Sustainability (left)
Bioenergy Research & Demonstration Facility (right)

THE UNIVERSITY OF BRITISH COLUMBIA (UBC) CAMPUS is a 1,001 acre (405 hectare) community of academic, residential, commercial, agricultural and operational facilities where sustainability is integrated into research, teaching, administration, planning and operations. As part of the Campus as a Living Laboratory (CLL) initiative, UBC is applying a sustainability "gradient" framework where each new capital project is intended to exceed the performance of the previous ones, continually raising the level of overall sustainability performance. The goal is to transform the campus into one that upholds "regenerative" principles, which go beyond conventional green standards by creating buildings and infrastructure that provide net-positive environmental and human well-being benefits.

In recent years, life cycle assessment (LCA) and a distinct but related methodology, life cycle costing (LCC), have emerged as key decision-making and enabling tools in the design and construction of sustainable projects at UBC. Their ability to measure both the environmental impacts and financial performance of materials and services throughout their whole life cycle provides a framework to compare materials, products and designs using qualifiable benchmarks and following internationally recognized standards and protocols. The results of the assessments supply scientifically validated information that enable designers, clients and contractors to objectively evaluate options and to make design decisions based on the priorities of a project.

Life cycle costing provides a means of analysing the present and future financial impacts of investment decisions. It is often coupled with LCA to determine the financial profiles associated specifically with environmental concerns. In today's building industry, achieving high levels of sustainability performance can have construction cost (first costs) implications. These generally manifest as higher priced products and materials and increased labour costs compared to conventional buildings. However, these higher initial costs can be seen as an investment to be recouped over time. Sustainable buildings consume fewer resources and contribute more directly to the well-being of inhabitants, leading to better health and increased productivity. The payback can be demonstrated by calculating the total cost of ownership (TCO) of sustainable buildings, using standard life cycle costing methodologies such as Net Present Value (NPV) and Internal Rate of Return (IRR), and comparing that with the TCO achieved by equivalent conventional buildings.

In construction projects, life cycle assessment creates a comprehensive picture of materials, products, assemblies and whole buildings. This is done by measuring the impacts of materials and energy of the built environment on ecosystems and human health. Impacts are assessed at each stage of the life cycle from "cradle-to-grave", that is: extraction, transportation, processing, production, refinement, installation, use, deconstruction and disposal. Materials that can be reused or recycled, like many wood products, have a "cradle-to-cradle" application that extends their useful life, increasing their value and improving the building's economic viability.

As part of a series of pilot project demonstrations, UBC has applied LCA and LCC methodologies on a number of recent campus projects. LCA and LCC have proven to be important tools supporting the design decision-making process and meeting the high performance goals of sustainable projects, and they are being institutionalized for new campus projects. Over time, UBC will systemically embed LCA and LCC in the planning and design processes of all new capital projects, as well as the assessment and development of renovation or demolition strategies for existing buildings.

Embodied energy is the measure of the energy consumed at various stages of a product's life cycle. In a building this is closely connected to material choices, particularly the structure. It is distinct from operating energy, which depends on factors such as types of building systems, wall insulation and air tightness, lighting, and occupant behavior. As building performance and energy efficiency increases, operating energy is reduced and embodied energy takes on greater significance, since it comprises a substantial proportion of the building's total life cycle energy use. Life cycle assessment provides a mechanism to measure these two forms of building energy consumption and evaluate design choices accordingly.

CENTRE FOR INTERACTIVE RESEARCH ON SUSTAINABILITY

COMPLETED IN 2011, the Centre for Interactive Research on Sustainability (CIRS) is the flagship project of UBC's Campus as a Living Lab initiative. It is an academic building designed to meet regenerative sustainability principles – to have a net-positive impact on its environment and the lives of its human inhabitants. The vision behind CIRS is to accelerate the adoption of more sustainable practices throughout society. It seeks to become the new benchmark that future sustainable buildings surpass. Throughout the CIRS design process, life cycle analysis was performed to assess the environmental impacts of different material options for the building structure and cladding.

The structural life cycle assessment compared five different systems (FIG 01):

- Option 1: all concrete;
- Option 2: concrete beams, columns, walls and floors with steel stud infill walls;
- Option 3: glulam beams and columns, hollow core concrete floor with steel stud infill walls;
- Option 4: glulam beams and columns, composite wood floor with steel stud infill walls;
- Option 5: glulam beams and columns, composite wood floor with wood stud infill walls.

Option 5 was selected because it met a number of criteria for the project, including providing significant carbon storage. One of CIRS' primary goals was to optimize the amount of carbon stored in the building in order to offset the overall carbon emissions of the CIRS construction project. This has subsequently become a priority for new UBC buildings. For the different cladding material options, the life cycle assessment evaluated:

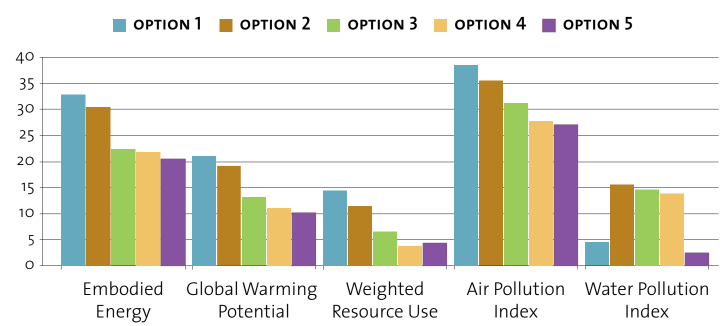
- distance from location of manufacture to site;
- material cost;
- amount of embodied greenhouse gas (GHG) emissions (GHGs emitted from the extraction, manufacture, transportation of products and their construction in the building); and
- contribution towards the achievement of green rating system requirements. The project team had set high performance standards for CIRS, targeting LEED Platinum certification and Living Building Challenge recognition and used LCA to help achieve those targets.

The different cladding options included: panels of tongue and groove western red cedar, granite, basalt, composite pulp, and cementitious materials (sourced regionally and from abroad) as well as a white concrete brick (a more sustainable version of the traditional white clay brick used in the historic campus core).

At the conclusion of the assessment, the preferred materials were locally sourced and manufactured white concrete brick and western red cedar three-ply panels with a natural stain. These two materials performed the best across all the assessment criteria and complemented each other to create a beautiful façade for the building.

To fully evaluate the results of the design and construction process of CIRS, a whole building LCA is being conducted as part of a UBC research project by a group of UBC students. The whole building LCA measures inputs, processes and outputs for the building's resources, energy and materials and assesses the impacts of specific functions within the building. The study is intended to validate the project's sustainability claims and provide a benchmark of the environmental impacts of a state-of-the-art sustainable building in the campus-wide data-base of UBC academic buildings. The life cycle inventory data will be available for use in future LCA studies for CIRS and other campus buildings.

FIGURE 01



BIOENERGY RESEARCH & DEMONSTRATION FACILITY

THE BIOENERGY RESEARCH & DEMONSTRATION FACILITY (BRDF) is a combined heat and power (CHP) generation plant that is part of UBC's campus wide strategy to meet growing energy demand while reducing greenhouse gas emissions. The BRDF co-generation system utilizes locally harvested biomass feedstock (wood chips) to produce heat and electricity for academic buildings. One of the first facilities of its kind, the operation of BRDF is combined with research and teaching opportunities under the Campus as a Living Lab initiative. As part of that research agenda, UBC researchers conducted a comprehensive post-construction cradle-to-grave LCA on the building's structure and envelope.

BRDF is the first North American demonstration of an industrial facility utilizing cross-laminated timber (CLT). CLT is an engineered wood product created by the cross-grain layering of pieces of lumber into panels, which can be used in floors, walls or roofs. BRDF is constructed primarily of CLT panels that function as composite assemblies with glulam columns and beams. The LCA performed on the facility included a comparison of the environmental performance of the engineered wood (CLT) building system with that of a primarily concrete structural system (the typical choice for this type of building).

The result of the BRDF LCA showed that engineered wood was the preferred choice over concrete because it had lower environmental impacts over its life cycle. In the analysis, the wood system consumed less fossil fuel and used fewer natural resources per unit area than concrete. It also had lower global warming potential and lower negative human health respiratory effects.

FIGURE 02

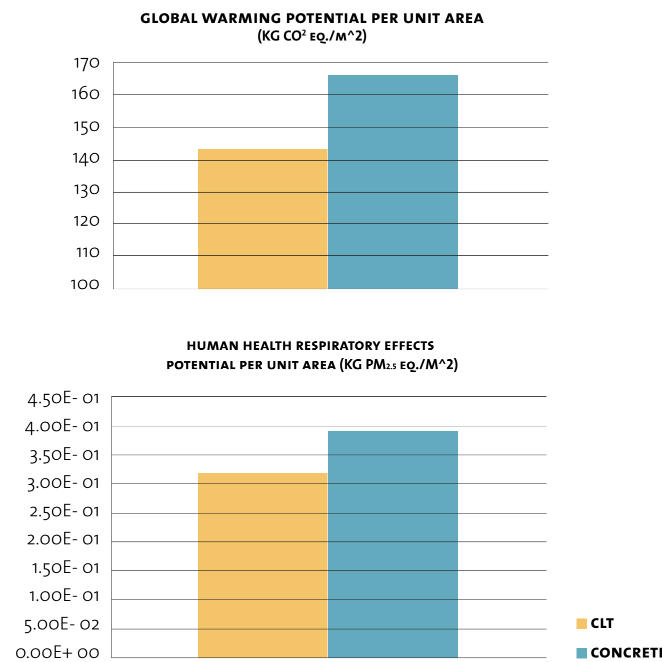


FIGURE 02

CLT was found to have lower global warming potential because its manufacturing process releases less greenhouse gases than concrete. It has lower negative human health respiratory effects because its manufacturing process releases less particulate matter.

WESBROOK COMMUNITY CENTRE

THE WESBROOK COMMUNITY CENTRE (WCC) is a large community gathering and recreation centre located in the Wesbrook Place neighbourhood at UBC's Vancouver campus. It houses fitness facilities, general use rooms, a teen centre, a childhood care centre and a café.

A partnership of UBC Properties Trust, the University Neighbourhoods Association (UNA) and CIRS commissioned an LCA study to support the design decision-making process for the Community Centre. The first part of the study focused on cradle-to-gate (the overall design and construction of the building, excluding operations and deconstruction) screening-level analysis of the environmental impacts of three preliminary building designs (**FIG 03**):

- Option 1 used a structural and envelope material mix of concrete and steel products.
- Option 2 used wood products, notably cross laminated timber (CLT) and glulam.
- Baseline used a material mix between those of Option 1 and Option 2.

These options were analyzed for impacts associated with global warming potential, fossil fuel consumption, ozone depletion, photochemical smog, acid rain, and eutrophication (algae bloom) of bodies of water. The LCA provided information on how the proposed building would perform environmentally and the potential influence of different materials, which the design team used to develop a low impact final design for the Community Centre.

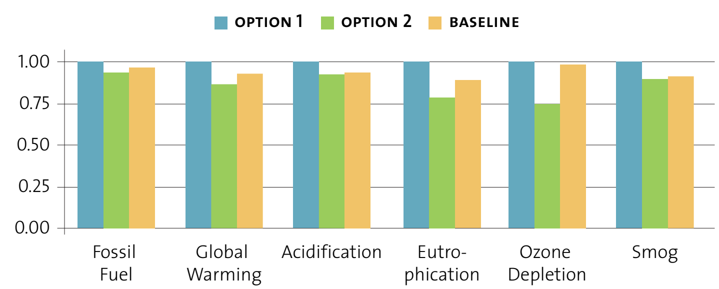
The Wesbrook Community Centre LCA focused on the structural system and building envelope components because they comprise the largest of all the building assemblies. It also showed that the building envelope (roof and perimeter walls) and foundation accounted for a significant majority (76 – 90 per cent) of the environmental impacts of the whole building and therefore recommended that the design team focus on specifying low impact materials for these assemblies. The results of the LCA indicated that utilizing a wood structure - in particular CLT wall, floor and roof panels - would improve the performance of the building as compared to more conventional concrete and steel systems.

As a result of the LCA, UBC determined that 90-100 per cent of the environmental impacts of building materials were embodied in the resource extraction and manufacturing processes. The LCA report includes a recommendation that future design teams and policy-makers specify materials with lower manufacturing impacts.

The report also indicated areas of study that would benefit from further research and development to strengthen the application and value of using LCA in project design decision-making. These include:

- further engaging product and materials suppliers in the project goal setting phase to acquire more comprehensive LCA information;
- extending the investigation beyond construction to explore the actual impacts of design-decisions on building operations and maintenance;
- combining the LCA with an LCC application to develop a cost/benefit analysis for capital investment that considers both the environmental and financial implications of decisions; and
- incorporating a more complete analysis of the carbon emissions and sequestration associated with building materials into early project stages to explore the potential of carbon offset, taxes and trading.

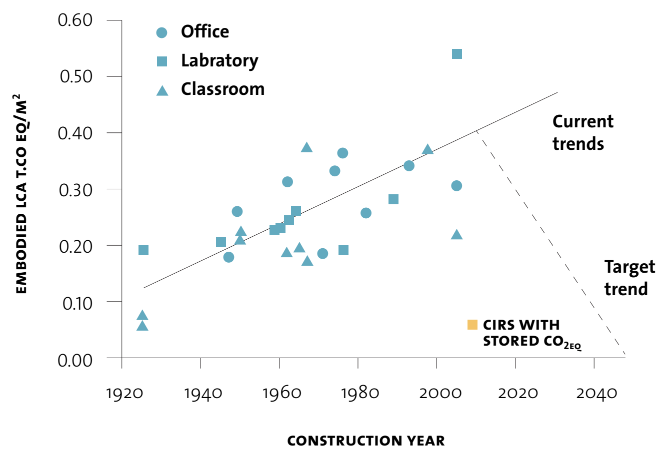
FIGURE 03



LCA DATABASE

THE LCA ALLIANCE, a UBC student-led research group, is currently creating the largest building-scale LCA database in North America. Working in collaboration with the Athena Sustainable Materials Institute, UBC Infrastructure Development and the department of Civil Engineering, students have analysed 52 per cent of the campus core buildings at UBC to date. Initial phases of the project have encompassed the environmental impacts of building design decisions (cradle-to-gate) and focused on the structure, envelope and operational energy usage associated with interior space conditioning. Industry accepted computer programs were used to analyze the data through a set of environmental characterizations (such as raw resource use, human respiratory impacts and ozone depletion). The result is a whole building LCA model with a complete environmental impact profile for each building.

The application of the information compiled in the LCA database is intended for use at the building-scale to assist in the potential future performance upgrades to existing buildings and systems, and to inform the design of new buildings. At the campus scale, the database can be used to carry out comparisons of different materials, types of structures and uses between UBC buildings over time, as well as highlight trends and patterns. This information can in turn inform UBC's planning and development policies and help establish quantifiable sustainable development guidelines for future construction, renovation and demolition projects.



Over time, the embodied greenhouse gas emissions of campus buildings (measured here in tonnes of equivalent CO_2) have grown, mostly due to an increased use of concrete. CIRS provides an example of a way to reverse the trend by increasing the use of wood in building construction. The wood structure of CIRS stores more carbon than was emitted during the construction of the whole building. New engineered wood products, with higher dimensional stability and predictable performance, are making wood a viable material for use in large-scale buildings and non-traditional applications, such as hybrid wood-concrete-steel.

PROJECT CREDITS

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LCA STUDY
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LCA STUDY
Life Cycle Assessment of the Wesbrook Community Centre Project by Coldstream Consulting and UBC LCA Working Group

LCA DATABASE

GRAPH
created by Stefan Storey, information from the LCA Building database

LCA REPORT
UBC LCA whole building database, In-house report by Rob Sianchuk and Stefan Storey

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Published November 2013