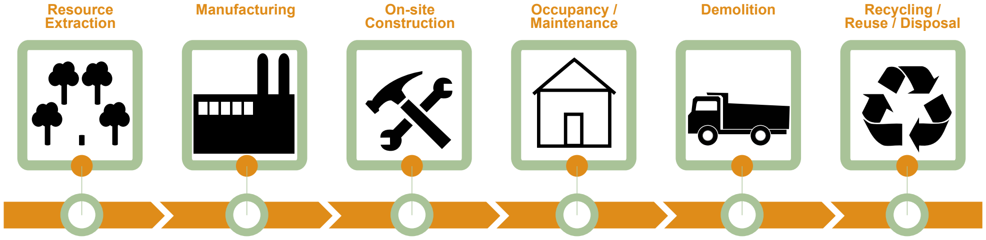
# Wood Specification:
# Life Cycle Assessment

The best way to determine the full environmental impacts of a building product or design is through life cycle assessment (LCA). LCA analyzes the total environmental impacts of all materials and energy flows, either as input or output, over the life of a product from raw material to end-of-life disposal or to rebirth as a new product. For buildings and building products this includes resource extraction, manufacturing, on-site construction, occupancy, and eventual demolition and disposal or reuse. Some countries (e.g., France and Germany) have already adopted codes and standards requiring life cycle assessment and the submission of Environmental Product Declarations (EPD). Some green building rating systems also include (or plan to include) recognition for LCA.

## Why Life Cycle Assessment Adds Value

- Sustainable design is complex and integrated. One way to understand the complex interaction of factors is through life cycle assessment. To date, green building design has focused heavily on minimizing the ongoing impacts of building operation, including energy use, water use, and maintenance impacts. Yet, a successful green building strategy should also address the upstream environmental burdens of the building materials and products.
- Commercial building clients are looking more closely at the environmental impacts of their operations and investments. Spurred by regulation and market forces, many corporations are committing to reporting their quality assurance and environmental initiatives and to tracking their improvements.
- Life cycle assessment provides measurable outputs that can help clients make meaningful decisions that not only affect their real estate portfolio but also inform their climate change mitigation strategies and their corporate marketing and recruitment efforts.
- Improved understanding of the long-term impacts of material choices in buildings can also guide capital planning for renovations and retrofits. LCA provides a methodology for specifiers to make informed choices about the environmental footprint of products as weighed against intended service life; anticipated replacement can protect asset value and future-proof investments.
- The life cycle assessment process is defined under ISO 14040/14044 (Environmental Management—Life Cycle Assessment—Principles and Framework / Environmental Management—Life Cycle Assessment—Requirements and Guidelines) which is part of the internationally recognized series of standards that address environmental management and is familiar to most businesses. Incorporating life cycle assessment positions a business as an industry leader and provides it with a competitive advantage, particularly in markets where LCA is recognized. Taking a proactive position also reduces costs associated with future regulatory compliance.



Life Cycle of Building Products

## Terminology

Typical environmental impacts of interest:

**Material usage:** amount of material used, expressed in terms of mass and/or volume.

**Embodied energy:** amount of energy associated with extracting, processing, manufacturing, transporting, and assembly of building materials.

**Global Warming Potential (GWP):** a measure of how much a given mass of greenhouse gas is estimated to contribute to global warming. It is a relative scale which compares the gas in question to the same mass of carbon dioxide (the GWP of which is by convention equal to 1). A GWP is calculated over a specific time interval which must be stated whenever a GWP is quoted.

**Air pollution:** sulphur dioxide, nitrous oxides, methane, particulates, and volatile organic compounds.

**Solid waste generation:** solid waste generated during manufacturing and construction.

**Water consumption:** quantity of water use associated with a material process.

**Water pollution:** the effluent deposited into water bodies.

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## Wood: A Carbon-neutral Building Material

- Manufacturing of wood products requires less total energy, and in particular less non-renewable (fossil) energy, than the manufacturing of most alternative materials.
- The drying process accounts for most of the energy used in the manufacture of wood products. Wood processing residues (such as sawdust) are commonly used to fuel the drying, thus the carbon emissions from wood product manufacturing are generally much lower than those associated with non-wood products.
- Trees store carbon accumulated during their growing period. Assuming sustainable forestry is practiced whereby trees are replenished as they are harvested, wood represents a very low carbon—and potentially carbon-neutral—product choice.
- Timber-based building products continue to store carbon absorbed during the tree's growing cycle. The carbon content comes from fixed atmospheric $CO_2$ via photosynthesis. The capacity of trees to absorb and store carbon can be factored against the carbon emissions incurred during drying, processing, and transporting wood products. The result may be a carbon-neutral building material.

## How to Include Life Cycle Assessment in Design

Environmental responsibility in building design requires consideration of both upstream and downstream impacts. Yet, most green building programs and rating systems do not systematically look at the whole building from a life cycle perspective. For example, Leadership in Energy and Environmental Design (LEED®) promotes the goal of lowering environmental impacts of products by awarding points for recycled content or for the use of local materials, and by rewarding materials that are low in volatile organic compounds.

In reality, assessing the environmental merits of a product is complex and often based on competing criteria. For instance, recycled paint from a local source may have high volatile organic compound content. In contrast, LCA takes a cradle-to-grave approach by evaluating all dimensions of a product or building in order to determine the most sustainable option.

Effective incorporation of LCA into design requires obtaining validated information about products used in a building's construction. Environmental information sheets (provided by suppliers as part of their submission for rating system application) are the current means of understanding environmental impacts but these sheets often do not provide a complete picture of a product's life cycle in a format that makes it easy to compare products.

While detailed LCA may be beyond the realm of contemporary architectural practice on a project-by-project basis, the market is moving towards demanding greater accountability of manufacturers. Ultimately, complete life cycle information will be provided in Environmental Product Declarations (EPDs).

Applicable worldwide, EPDs are a standardized (ISO 14025) tool for communicating the environmental performance of a product or system. They include information about the environmental impacts associated with a product, such as raw material acquisition, energy use and efficiency, content of materials and chemical substances, emissions to air, soil, and water, and waste generation.

EPDs are increasingly provided in Europe and follow the product labelling protocols set out in ISO 14025 (Environmental Labels and Declarations—Type III Environmental Declarations—Principles and Procedures) and ISO 14040 (Environmental Management—Life Cycle Assessment—Principles and Framework).

Some countries have already committed to their use. Starting in January 2011, France is requiring product and packing materials to declare "carbon equivalents and the consumption of natural resources or impacts on natural compartments.[1]"

The United States and Canada are also exploring the use of EPDs. To this end, the North American wood industry has invested in life cycle assessment research and education programs to better articulate the LCA benefits of wood.

Rigorous LCA methods require significant time and financial resources. From the perspective of the architect, it is often difficult to justify the development of several design alternatives for the purpose of objective comparison. However, instilling LCA thinking at the macro level is an easy first step that offers immediate benefits. In the early design phases, a whole-building analysis can help with basic questions like those about structural system selection. In later phases, product-to-product comparisons can help fine-tune a building's environmental performance. For example, being familiar with the relative embodied energy values for commonly used materials can broaden the palette of material options. LCA also offers valuable indicators which assist in the efficient allocation of limited dollars to the most critical and practically attainable strategies for achieving the highest building performance.

[1] Loi Grenelle 2 (http://affichage-environnemental.afnor.org/actualites/articles-et-communications/loi-grenelle-2).

## Next Steps: Where Proficiency in Life Cycle Assessment can Lead

- It is inefficient for the general practitioner to attempt to perform detailed life cycle assessment studies unless the intention is to devote significant resources to making that endeavour a specialty. As a first step, start by taking a product-to-product approach to LCA. With experience, move to assessing assemblies and finally the whole building.
- In order to accurately evaluate the impacts of green building on the budget, it is important to look beyond first costs. Increasingly, architects are using life cycle assessments to evaluate and quantify the economic and environmental costs and benefits of materials and products over their lives.
- Life cycle assessment methods are becoming more standardized, and a range of tools are emerging to provide comparable product-level evaluations. Whether or not reliable LCA information is available, always apply life cycle thinking and critically review any product information to support design and product choices.
- LCA will continue to be shaped as research evolves and grows more robust over time. The evolving body of knowledge that is part of whole-building life cycle assessment can help to inform better design decisions in service to a healthier planet.

## Life Cycle Assessment Tools

LCA software offers building professionals powerful tools for comparing products and calculating the lifetime impacts of building products or assemblies. Data gathered via LCA are of particular interest to long-term building investors who are concerned about the overall impacts of their buildings and about protecting the value of their assets.

A summary of tools is available on the website of the United States Environmental Protection Agency (http://www.epa.gov/nrmrl/lcaccess/resources.html). The most popular are listed below.

### For General Building Professionals

- ***ATHENA EcoCalculator for Assemblies* (www.athenasmi.ca):** free inventory data tool for comparing assemblies or whole buildings, based primarily on the widely acclaimed US Life Cycle Inventory Database and published Canadian data.
- **Athena Impact Estimator for Buildings (www.athenasmi.org/tools/impactEstimator/index.html):** developed in Canada and applicable North America-wide.
- **BEES (http://www.nist.gov/el/economics/BEESSoftware.cfm):** easy-to-use, US-based, free tool for product-to-product comparisons; based on proprietary, unpublished data.
- **ENVEST (http://envestv2.bre.co.uk/):** UK-based, life cycle assessment-based building design tool. It addresses only the whole building, and provides results in highly summarized "ecopoints."
- **Forest Industry Carbon Assessment Tool (FICAT) (http://www.ficatmodel.org/landing/index.html):** available for download free of charge, calculates carbon footprints of the effects of forest-based manufacturing activities on carbon and greenhouse gases along the value chain.

### For Life Cycle Assessment Practitioners

- **GaBi (www.gabi-software.com):** a tool from Germany, comprised of primarily European data.
- **SimaPro (http://www.pre.nl/simapro):** a tool from the Netherlands; includes a comprehensive suite of databases for building materials applicable to the United States, Japan, and various European countries.

## Life Cycle Assessment Thinking: Global Warming Potential

This table illustrates how LCA thinking can be employed. The simplified example uses publicly available data and industry averages to present just one facet of life cycle assessment: global warming potential. At 62 storeys and 646 ft (197 m) high[2], the Shangri-La Hotel and Residences is the tallest building in Vancouver, British Columbia. It is also the heaviest.[3]

| Building statistics (simplified) | |
|---|---|
| The building's structure comprises 122,400 tonnes of concrete[a] plus 7,000 tonnes of reinforcing steel.[b] | 122,400 + 7,000 = 129,400 tonnes<br>Total weight of structure = 129,400 tonnes |
| **Embodied energy of structure** | |
| Embodied energy is the non-renewable energy consumed in the acquisition of raw materials, and in their processing, manufacturing, transportation to site, and construction.[c]<br>Embodied energy of concrete is 1.3 GJ/tonne.[d]<br>Embodied energy of recycled steel is 8.9 GJ/tonne.[e] | Concrete: 122,400 x 1.3 = 159,120 GJ<br>Steel: 7,000 x 8.9 = 62,300 GJ<br>Total embodied energy of the structure = 221,420 GJ<br>The same amount of energy would heat 2,088 Canadian homes for 1 year.[f] |
| **Embodied energy of structure vs. annual operating energy (using industry averages)** | |
| The total gross floor area of the building is 696,339 ft$^2$ (64,692 m$^2$).[g]<br>The average energy use intensity (EUI) in British Columbia:[h]<br>Hotels (30% total GFA) = 2.500 GJ/m$^2$/y<br>Apartments (70% total GFA) = 0.651 GJ/m$^2$/y | Total annual operating energy use:<br>Hotels 2.5 x 64,692 x 0.3 = 48,519 GJ/y<br>Residences 0.651 x 64,692 x 0.7 = 29,480 GJ/y<br>Grand total = 77,999 GJ/y<br>The embodied energy in the structure is equivalent to the total operating energy for the building for 2.8 years. |
| **Embodied greenhouse gas emmisions** | |
| The production of 1 tonne of Portland cement emits 1 tonne of $CO_2$.[i] On average, Portland cement comprises 10% of structural concrete.<br>Canada produces 15 million tonnes of steel/y.[j]<br>In 2008, $CO_2$ emissions were 14 million tonnes, equating to roughly 0.9 tonnes of $CO_2$ per tonne of steel produced.[k] | $CO_2$ emissions associated with production of structural materials:<br>Concrete: 1 x 12,240 = 12,240 tonnes $CO_2$<br>Steel 0.9 x 7,000 = 6,500 tonnes $CO_2$<br>Total $CO_2$ emissions generated from the manufacture the Shangri-La's structure = 18,740 tonnes of $CO_2$. This is the same as putting 3,920 passenger vehicles on the road for 1 year.[l] |

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[a] 51,000 m$^3$ × 2,400 kg/m$^3$ (2,400 kg/m$^3$ = average weight of concrete). Emporis.com—The World's Building Website (http://www.emporis.com/application/?nav=building&lng=3&id=176375).

[b] Emporis.com—The World's Building Website (www.emporis.com/application/?nav=building&lng=3&id=176375).

[c] "Measures of Sustainability: Life Cycle Assessment." *Canadian Architect*. (www.canadianarchitect.com/asf/perspectives_sustainibility/measures_of_sustainablity/measures_of_sustainablity_lca.htm)

[d] Embodied energy data from "Measures of Sustainability: Life Cycle Assessment." Assumes Canadian national averages for transportation impacts.

[e] Ibid.

[f] An average Canadian home consumes 106 GJ of energy. *2007 Survey of Household Energy Use*. Office of Energy Efficiency, Natural Resources Canada (http://oee.nrcan.gc.ca/publications/statistics/sheu-summary07/sheu.cfm).

[g] Living Shangri-La. Skyscraper Source Media, 2010 (http://skyscraperpage.com/cities/?buildingID=9790).

[h] "2030 CHALLENGE Targets: Canadian Residential Regional Averages—Averages for Site Energy Use and 2030 Challenge Energy Reduction Targets by Space/Building Type" (http://www.architecture2030.org/files/2030_Challenge_Targets_Res_Canada.pdf.).

[i] Ecosmart (www.ecosmart.ca).

[j] Canadian Steel Producers Association (CSPA) (www.canadiansteel.ca).

[k] CSPA Environmental Report 2010 (www.canadiansteel.ca).

[l] 4.78 tonnes/y. "Emission Facts: Greenhouse Gas Emissions from a Typical Passenger Vehicle. United States Environmental Protection Agency, 2010" (www.epa.gov/oms/climate/420f05004.htm).

[2] Emporis.com—The World's Building Website. (www.emporis.com/application/?nav=building&lng=3&id=176375).

[3] Living Shangri-La has Vancouver's Heaviest Tower. Journal of Commerce, June 2007. (www.journalofcommerce.com/article/id22912).

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## What to Ask Suppliers

Encourage product manufacturers to perform life cycle assessments on their products and make the results available. Ask product reps for LCA data. Refer to ISO-standard Type III Environmental Product Declarations (third-party reviewed LCA results), and/or the various software tools to obtain data. Ask key questions about the data that are provided in order to assess the reliability and applicability to design decisions. Examples of such questions include:

- What are the sources of the data? How much is based on primary information obtained directly from the operations, as opposed to databases of industry-average data? Of the industry average data, is it regionally specific (U.S. as opposed to Europe) and fully transparent to users or peer reviewers?
- What assumptions are included about the functional unit and the service life of the product(s) in question? Do these correspond to the project at hand?
- What is included in any life cycle assessment or life cycle cost calculation? Sometimes, certain materials or components are excluded, e.g., the resin in a composite wood product.
- What is assumed about the products' maintenance requirements and/or impacts on building operations?
- Do the impact categories included in the results capture the important information, or might the results be skewed by leaving out key categories?

## Resources

**Lawrence Berkeley National Laboratory, High-Performance Commercial Building Systems (http://buildings.lbl.gov):** is developing a set of life cycle cost tools for improving commercial building performance.

**Whole Building Design Guide—Life Cycle Tools (www.wbdg.org/tools/tools_cat.php?c=3):** developed by the National Institute of Building Sciences in the United States, provides a variety of life cycle cost and assessment tools.

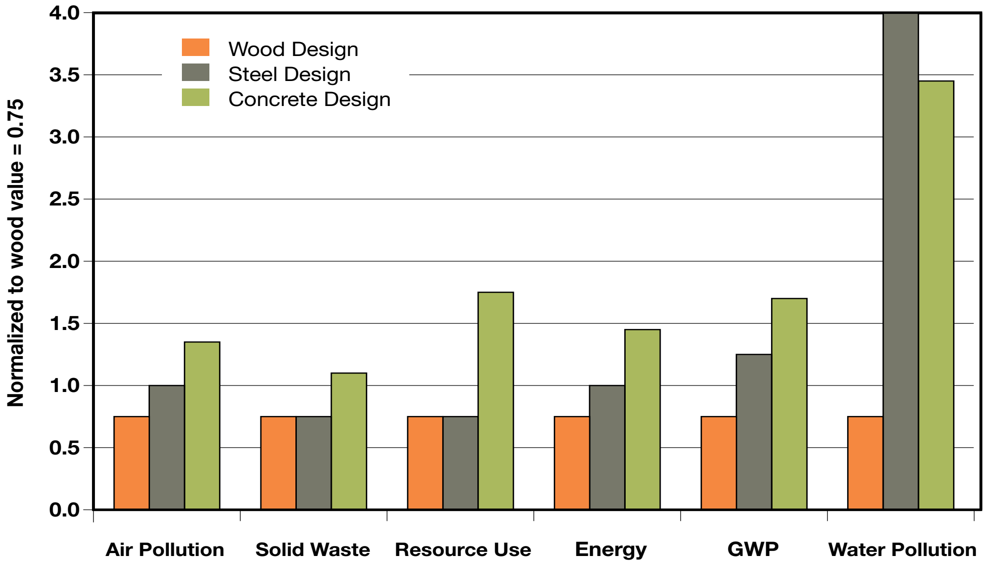
**European Commission, Life Cycle Thinking (http://lct.jrc.ec.europa.eu/):** home of the International Reference Life Cycle Data System which seeks to identify improvements to goods and services in the form of lower environmental impacts and reduced use of resources across all life cycle stages. The site includes a handbook and information about the European Platform on Life Cycle Assessment and the European Reference Life Cycle Database (ELCD core database v2 with 300+ processes).

**United Nations Environment Program, Life Cycle Initiative (http://lcinitiative.unep.fr/):** aims to bring science-based life cycle approaches into practice worldwide.

**www.naturallywood.com:** provides a database of 600 British Columbia-based suppliers of certified wood suppliers, plus a wealth of other resources.

**www.buildgreenwithwood.com:** a community for professionals to share innovations, connect with industry news, and find out more about building green with wood from sustainably managed forests.

**Embodied effects relative to the wood design across all measures**



(Left) In this graph, three hypothetical homes (wood, steel and concrete) of identical size and configuration are compared. Assessment results are summarized into six key measures during the first 20 years of operating these homes.

Source: Data compiled by Canadian Wood Council using the *ATHENA EcoCalculator* with a data set for Toronto, Ontario.

## Rule of Thumb

| Material | Embodied energy, ranked by density $MJ/m^3$ |
|---|---|
| Straw bale | 31 |
| Cellulose insulation | 112 |
| Mineral wool insulation | 139 |
| Aggregate | 150 |
| Soil-cement | 819 |
| Fiberglass insulation | 970 |
| Lumber | 1,380 |
| Stone, local | 2,030 |
| Concrete, block | 2,350 |
| Concrete, precast | 2,780 |
| Concrete (30 MPa) | 3,180 |
| Polystyrene insulation | 3,770 |
| Particleboard | 4,400 |
| Shingles, asphalt | 4,930 |
| Brick | 5170 |
| Plywood | 5,720 |
| Gypsum insulation | 5,890 |
| Aluminium, recycled | 21,870 |
| Steel, recycled | 37,210 |
| Glass | 37,550 |
| Carpet, synthetic | 84,900 |
| PVC | 93,620 |
| Paint | 117,500 |
| Linoleum | 150,930 |
| Steel | 251,200 |
| Zinc | 371,280 |
| Aluminium | 515,700 |
| Brass | 519,560 |
| Copper | 631,164 |

*Source: The Canadian Architect*

Note: this table does not differentiate the impacts and efficiencies of source energy generation used in extraction, transportation or manufacture. For example, the Swiss Minergie rating system (www.minergie.com) weights energy carrier and sources as follows: Biomass (wood, biogas) 0,5 Waste heat (sewage, industry, etc.) 0,6 Fossil fuels 1,0 and Electricity 2,0.

Note: Cubic metres may not be an appropriate unit for comparison between materials (not a functional unit).