About LCA

Life cycle assessment (LCA) is a scientific method for measuring the environmental footprint of materials, products and services over their entire lifetime.

At the Athena Sustainable Materials Institute, LCA is applied to construction products, building assemblies, whole structures, building portfolios and highways. Athena is North America’s leader in bringing the quantified environmental footprint science of LCA to the built environment.

The whole-life approach from resource extraction through manufacturing, transportation, installation, use, maintenance and disposal or recycling provides users with critical long-term information affecting design decisions across the spectrum of their work.

Life cycle assessment is often referred to as cradle-to-grave or cradle-to-cradle analysis and is essential for making green decisions, whether in product manufacturing or in building design. It is life cycle thinking applied to a product: what is involved to make a product and transport it to an installation site; what inputs and waste will occur related to using the product over its life, and what will happen to the product when it is no longer needed? Without measured data, we can only guess about the true footprint of our choices.

Life cycle thinking enables consideration of trade-offs; one decision affects other elements in the larger picture. For example, if we increase recycled content in a product, have we created a problem for further recycling or disposal later? Sometimes environmental decisions simply shift the burden to another part of the environment. LCA ensures a comprehensive perspective to help avoid this.

Life cycle thinking isn’t about distinguishing good products from bad products. It’s about informed decision-making. More data enables better tools for decisions. Everything has environmental impact. LCA enables informed consideration of those impacts.

Who Does LCA & Why?
Life cycle assessment is the most reliable method to verify environmental impacts and support claims. It provides designers, regulators and engineers with irrefutable information for exploring decisions in each life stage of materials, buildings, services and infrastructure. The Athena
Sustainable Materials Institute applies LCA exclusively for the construction sector, but LCA is widely used across other sectors as well.

LCA identifies environmental hot spots in products and materials and establishes the benchmark, against which improvements can be measured. Companies use LCA to demonstrate full footprint transparency and corporate credibility to stakeholders and customers. LCA is also used in new product research and development, when environmental footprint is important to the future marketing or cost structure of a product.

LCA is integrated across sectors and industries. LCA is recognized in business rationales as consumer and regulatory environmental expectations are increasing in demand and sophistication.

LCA’s growing significance is evident in the next wave of eco-labeling: environmental product declarations (EPDs), which report LCA data. EPDs are often likened to nutrition labels on food packages. Already prevalent in Europe and Asia, EPDs are coming to North America, driven by market forces such as a new pilot credit in LEED and a new MR credit in LEED 2012. Suppliers to the construction sector are developing LCA data and EPDs to meet this market demand.

The benefit to LCA is simple: reliable, transparent data for both manufacturers and consumers.

**LCA in Construction Practice**
In North America, LCA is rapidly becoming more integrated in green design codes and standards. The number of leading-edge designers currently bringing LCA into their practices is growing because it’s a tool that defines their work and addresses their clients’ demand for accurate footprint information.

Athena tools and data are used on their own, or in conjunction with LEED®, Green Globes™, the ICC 700 National Green Building Standard, ASHRAE 189.1, CalGreen and the International Green Construction Code.

**LCA and LEED**
LEED has run two pilot credits that involve LCA, and has two new MR credits with LCA in the LEED 2012 draft (July 2011 2nd public comment draft).

LEED Pilot Credit 1 (Life Cycle Assessment of Building Assemblies and Materials—discontinued in Fall 2011) used the Athena EcoCalculator tool as a basis for awarding a point if the building design exceeded average performance. The results of this pilot are being used by USGBC in
developing a new MR LCA credit in LEED 2012.

LEED Pilot Credit 43 (Certified Products) is worth one point and available to all LEED rating systems except Homes, EB and ND. This credit has two pathways, and both have elements of LCA. Athena has published LCA data on most generic structural and envelope materials which would be applicable to this credit.

LEED 2012 (July 2011 2nd public comment draft) BD&C has a new MR Credit, Non-Structural Materials Transparency, worth 1-2 points, which is essentially the second path of Pilot Credit 43 described above. The LEED 2012 EB draft has a similar credit that applies to consumables, electric equipment like computers, and some lamps.

LEED 2012 (July 2011 2nd public comment draft) BD&C has a new MR Credit, Environmentally Preferable Structure and Enclosure, worth 1-3 points. This credit contains elements of previous MR credits for building reuse, recycled content, and local materials as well as offering a new LCA alternative compliance path (worth up to 2 points). In this path, designers use an LCA-based tool to assess the footprint of the building structure and enclosure, document results and subsequent design decisions, and demonstrate that the final design meets or exceeds national averages as published in USGBC tables. Athena has the only North American software for building and assembly LCA.

LCA and Green Globes
Green Globes™ was the first national building rating system in North America to integrate LCA as a credit. The Athena EcoCalculator for Commercial Assemblies is the basis for this credit; in fact, the EcoCalculator was originally developed to serve this purpose. Green Globes awards points for the educational experience of using LCA and does not credit any particular performance level. In 2010, ANSI/GBI 01-2010: Green Building Protocol for Commercial Buildings was officially approved; it is derived from Green Globes. In this standard, LCA is included as an alternative compliance path to prescriptive material requirements.

LCA and ICC 700
The International Code Council (ICC) 700 National Green Building Standard™ is a residential green standard initiated by the National Association of Home Builders. The current version gives points for the educational experience of using LCA. The 2012 draft has an alternative compliance path to prescriptive material requirements.

LCA and the IGCC
The International Green Construction Code from the International Code Council is currently in
public version 2.0 and headed for formal release in 2012. LCA is available as an alternative compliance path to prescriptive material requirements at the whole-building or assembly level.

**LCA and ASHRAE 189.1**
LCA is available as an alternative compliance path to prescriptive material requirements at the whole-building level.

**Calgreen**
In California’s 2010 draft Green Building Standards Code, LCA is available as an alternative compliance path to prescriptive material requirements at the whole-building level.

**Technical Details**
LCA is the performance approach to sustainable product or building design. It is the logical evolution from today’s reliance on prescriptive methods, whereby materials are deemed to have environmental benefits based on their attributes. For example, recycled content, rapid renewability, and local procurement are all assumed to be environmentally superior characteristics without any supporting data.

LCA measures actual performance, removing the assumptions. It is widely accepted in the international environmental research community as an appropriate method for scientific quantification of an environmental footprint.

**What is Being Measured**
In LCA, information is gathered at every phase of a product’s life, and viewed through the lens of defined environmental impact measures such as global warming potential, primary energy consumption, air and water pollution, and use of natural resources. Typically, LCA reports on these environmental effects due to a product, building or service:

- Fossil fuel depletion
- Other non-renewable resource use
- Water use
- Global warming potential
- Stratospheric ozone depletion
- Ground level ozone (smog) creation
- Neutrification/eutrophication of water bodies
- Acidification and acid deposition (dry and wet)
- Toxic releases to air, water and land
In LCA terminology, the effects associated with making, transporting, using and disposing of products are referred to as ‘embodied effects’, where the word “embodied” refers to attribution or allocation in an accounting sense as opposed to true physical embodiment. All of the extractions from and releases to nature are embodied effects, and there are also embodied effects associated with the production and transportation of energy itself (known as pre-combustion effects). Note that all phases, but the “use” phase in particular, include environmental accounting of associated activities and their products such as periodic cleaning and repainting. For example, a life cycle assessment for a deck needs to include the energy, water use and detergents involved with cleaning, the various impacts associated with coating products like stain, and the possible replacement of some boards over the life of the deck.

LCA in the Athena Software Tools
The Athena Impact Estimator and EcoCalculator are tools with detailed life cycle assessment in the background that provide access to LCA results on building products and report results for a building or assembly. Impacts are reported as a whole or broken down by six life cycle phases:

- Resource extraction
- Product manufacturing
- Construction of the building
- Building Occupancy and maintenance
- Building demolition
- Materials disposition (disposal or transfer for recycling or reuse)

See the diagram below and detailed description of the six life phases.
1. Resource Extraction

The life cycle of most building products starts with the extraction of raw resources like timber, iron ore, coal, limestone, aggregates and gypsum. The development of life cycle inventory data starts here, by tracking energy use and emissions to air, water and land per unit of resource. In addition to the actual harvesting, mining or quarrying of a resource, data from the extraction phase includes activities such as reforestation and beneficiation (a mining technique that involves separating ore into valuable product and waste). It also includes the transportation of raw resources to the mill or plant, which defines the boundary between extraction and manufacturing.

It is important to understand that LCA does not attempt to address all land-impact measures, many of which are tracked in other environmental metrics or regulatory programs. For example, effects on biodiversity, water quality, and soil stability are difficult to measure, may not have benchmarks or standards to provide a process for measurement, and are entirely site-specific at a small scale. Some of the broad resource issues of concern to many people are not included in LCA. The Athena databases tackle the problem with an ecological carrying capacity index. The index was developed from a survey of environmental and resource extraction experts to take account of relative extraction and land use effects for various raw materials.

2. Manufacturing

Manufacturing is the stage that typically accounts for the largest proportion of embodied energy and emissions associated with the life cycle of a building product. In Athena inventory studies, this stage starts with the delivery of raw resources and other materials to the mill or plant gate and ends with the finished product ready for shipment. The Impact Estimator software combines resource extraction and manufacturing into a single activity stage for results reporting purposes. The Athena Institute follows international guidelines for product LCAs addressing secondary components and assemblies, data sources and verification, system boundaries, the level of detail expected in inventory studies and a variety of other standard conventions and assumptions, to ensure that all building materials are treated impartially, in a comparable fashion. Athena product LCAs are performed in conjunction with experts in the relevant industries.

3. On-site Construction

The on-site construction stage is like an additional manufacturing step where individual products, components and sub-assemblies come together in the manufacture of the building. In the Athena tools, this stage starts with the transportation of individual products and sub-assemblies from manufacturing facilities to distributors in various Canadian and US regions. Average or typical transportation distances to building sites within each city are applied. This is an important life cycle stage that is often overlooked in life cycle assessments for products alone. In addition to building product transportation, waste generation, and the energy use of machines like cranes...
and mixers, the on-site construction activity stage includes such items as the transportation of equipment to and from the site, concrete form-work, and temporary heating and ventilation.

4. Occupancy/Maintenance
The occupancy stage takes into account functions like heating, cooling, lighting and water use, as well as the introduction of new products such as paints, stains, floor coverings and other interior finishes. It also considers that a building may be remodeled or reconfigured several times over its life, which introduces new products or systems. In the course of maintenance, some parts of a building will be altered or replaced, but other parts may not be seen or touched until the building is demolished. The Athena Institute has completed studies on the maintenance and replacement of building components for various North American regions. These data form the basis for the Impact Estimator occupancy stage results, whereby the expected life of a component such as roofing or windows is considered across the expected life of the structure so that appropriate product replacements are included. Athena has also developed an operating energy conversion calculator module which allows software users to enter their building’s annual operating energy by fuel type (as calculated using other tools such as energy simulation software); the Impact Estimator will include the pre-combustion and direct combustion emissions associated with the use of those fuels.

5. End of life
Demolition marks the end of a building’s life cycle, although it is not the end for individual component materials or products which face a subsequent recycling/reuse/disposal stage. The Athena Institute has developed LCA data for this life phase. In the Impact Estimator, the original building is charged with all demolition and transportation effects for the materials going to landfill. Recycling, reuse or disposal is the final stage in the life cycle of the individual components or products comprising a building. This part of LCA has a great deal of uncertainty; it involves trying to predict activities that are a long way in the future. The conservative approach is to assume demolition and disposal practices will always remain as they are today, because there is too much uncertainty involved in predicting future waste management practices. The Athena databases take account of recycled materials coming in as raw material for the manufacturing stage for various products (e.g., fly ash in concrete and steel scrap for steel products). The Impact Estimator does not give credit to a building for future reuse of demolition waste because that environmental impact is properly assigned to the next use of the material, not the current use. The Impact Estimator accounts for the environmental burden of demolishing the building and transporting materials to landfill. The Impact Estimator does not include greenhouse gas emissions or other environmental burdens due to the building materials residing in a landfill.
LCA Limitations

Life cycle assessment addresses only some of the characteristics that may fall under a heading of environmental or sustainability concerns. Critics of LCA are often unfairly expecting LCA to reach beyond its intended scope. LCA is a methodological tool that complements other methods of assessing “environmental” impact for a well-rounded picture. For example, LCA does not typically address ultimate human health effects—there are many other metrics and regulations in place for those concerns. A common example is the measurement of indoor air quality and its impact on human health.

Similarly, today’s mainstream LCA impact indicators do not directly address the ultimate effects on ecosystem stability or toxicity. Like human health effects, these have a high degree of difficulty and uncertainty in assessment. This is an area of on-going research in the LCA world. In both these cases, LCA typically stops at “mid-point” indicators rather than “end-point” indicators until the science of end-points becomes more resolved. A mid-point indicator, for example, is the potential for acidification of water bodies. An end-point indicator is a reduction in fish population.

LCA is also sometimes criticized for limited ability to account for land use impacts. These impacts are typically addressed more comprehensively by other metrics such as sustainable forest management programs. LCA does not replace those metrics. One of the difficulties in assessing the environmental effects of resource extraction is that so many of the environmental effects that concern people—for example, biodiversity, water quality and soil stability—are not easily measured and therefore are often minimally addressed in life cycle inventory studies. In addition, these types of impacts are highly localized and therefore difficult to account for in the mixing of commodity sources within the distribution processes that happen very far upstream in a product’s supply chain. North America lacks LCA protocols for land use impacts; in other words, what to measure and how to measure are not standardized nor even resolved. In Athena data, this issue is addressed with our index known as the “ecological carrying capacity effects of resource extraction.”

Life cycle assessment by definition has some uncertainty as with any calculation that involves assumptions about future conditions. In that sense, it is fundamentally no different than energy simulation. Other variables that affect confidence in or comparability of LCA results include quality of the underlying LCI data, attribution methods and selection of impact indicator frameworks. LCA has matured as a science from earlier days when two different LCA studies on the same products might come up with completely different results. LCA is now an increasingly standardized practice with third-party review and centralized data sources such as the USLCI database, which are helping to minimize disparities.
LCA is a rigorous science, but its precision should not be overstated. By simply introducing the notion of (roughly) calculating the environmental footprint of a building under design, LCA is already a huge leap forward in the evolution from prescriptive to performance-based green design. To expect that LCA will deliver results with a high degree of precision given all the variables involved is asking too much. Consider this limitation in the same light as energy simulations; rather than expect the tool to deliver an absolute performance prediction, LCA is best applied for relative comparisons, to help in choosing one path over another.

**LCA, LCI, LCIA, LCC: What’s the Difference?**

**Life cycle assessment (LCA)** is a multi-step procedure for calculating the lifetime environmental impact of a product or service. The complete process of LCA includes goal and scope definition, inventory analysis, impact assessment, and interpretation. The process is naturally iterative as the quality and completeness of information and its plausibility is constantly being tested.

LCI is the **life cycle inventory**, which is the data collection portion of LCA. LCI is the straightforward accounting of everything involved in the “system” of interest. It consists of detailed tracking of all the flows in and out of the product system, including raw resources or materials, energy by type, water, and emissions to air, water and land by specific substance. This kind of analysis can be extremely complex and may involve dozens of individual unit processes in a supply chain (e.g., the extraction of raw resources, various primary and secondary production processes, transportation, etc.) as well as hundreds of tracked substances.

LCIA is **life cycle impact assessment**, the “what does it mean” step. In LCIA, the inventory is analyzed for environmental impact. For example, manufacturing a product may consume a known volume of natural gas (this data is part of the inventory); in the LCIA phase, the global warming impact from combustion of that fuel is calculated. There are various methods globally for categorizing and characterizing the life cycle impact of the flows to and from the environment, which can somewhat complicate the comparability of different LCA studies. Other variables in LCIA include the system boundary (how far upstream, downstream and sidestream does the analysis go), the functional unit (what is the volume/mass/purpose of the object being assessed), and specific LCIA methods such as allocation (how are impacts assigned to the product and by-products, on what basis). When comparing two LCA studies, these factors are critical to understanding if the comparison is apples-to-apples.

LCI and LCA should not be confused with **life cycle costing**. LCC is another life cycle approach (i.e., cradle to grave) but it looks at the direct monetary costs involved with a product or service and not environmental impact.