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Integrating LCA into Green Building Design

By Shannon Lloyd, PhD, Anne Landfield, and Brian Glazebrook

During the design process, a broad range of stakeholders—architects, engineers, designers, contractors, subcontractors and owners—combine technical expertise to produce one-off buildings with long life spans. They must consider the consequences that their decisions have on many performance criteria—building cost, intended functionality, and occupant comfort, safety, and aesthetics. Green building design is an integrated design approach for evaluating and minimizing the potential environmental impacts of a building while also evaluating and optimizing the many other performance criteria.

The green building design process focuses on using energy, water, and materials more efficiently in the design and operation of a building. Green buildings often combine strong environmental performance with increased economic, health, and productivity performance. While decisions made throughout a building's useful life influence the impact it can have on the environment, the critical time to employ green building principles is during the design process.

The top figure on page 53 shows a hypothetical comparison of when committed and incurred environmental impacts occur. It assumes that the determination and realization of environmental impact during a building's life cycle follow a similar pattern to that of building cost. The horizontal axis represents the building life cycle stages. During site selection and early design, various sites and building types are considered. In later design phases, the specific design of the building and the materials, components, and systems that will be used are selected. Most of a building's material, energy, and environmental loadings are likely to be committed during the design phase, whereas the environmental impacts attributed to a building occur largely during its use phase and may extend beyond the building's useful life. The opportunity to reduce the building's environmental impact decreases substantially after it has been designed and built.

Green Building Design and LCA

Evaluating the environmental consequences of a specific building design is difficult because every building is a unique, complex system of interrelated

components and subsystems. Efforts to optimize a single performance criterion, such as environmental impact, may affect other performance criteria. Given the long life cycles of most commercial, industrial, and institutional structures, reducing the environmental impact requires designers to use long-range planning horizons. Finally, environmental impact depends not only on the building system, but also on its interaction with the natural environment and its occupants.

In order for Building Teams to be able to balance environmental concerns with other performance requirements, they need clear and concise information. For certain decisions during the design process, qualitative guidance, such as design checklists or guidelines, make sense. For other decisions, however, qualitative information may not be sufficient for evaluating the environmental tradeoffs between different building materials, products, and designs. In this case, quantitative information, such as that generated through a life cycle assessment, provides the most value.

LCA provides a systematic approach to evaluating the environmental impacts of a product or system over its entire life cycle. As the lower figure on page 53 shows, the building life cycle includes the extraction of raw materials that make up the building, manufacturing building components or products, transporting and installing building materials and products, and operating, maintaining, and decommissioning the building. By integrating LCA into the building design process, design and construction professionals can evaluate the life cycle impacts of building materials, components, and systems and choose the combinations that reduce the building's life cycle environmental impact.

Several types of green building tools have been developed to help building designers incorporate LCA into building design. They can be used to guide general building planning, select building materials and components, and evaluate complete building designs. The amount of LCA expertise and time required to employ the different types of tools varies widely. The appropriate tool depends on a project's specific environmental objectives and budget.

The following tools have been used to incorporate LCA into building design: green building standards and rating systems, tools for evaluating building materials and components, software for evaluating whole buildings, and general LCA software.

1. Green Building Standards and Rating Systems

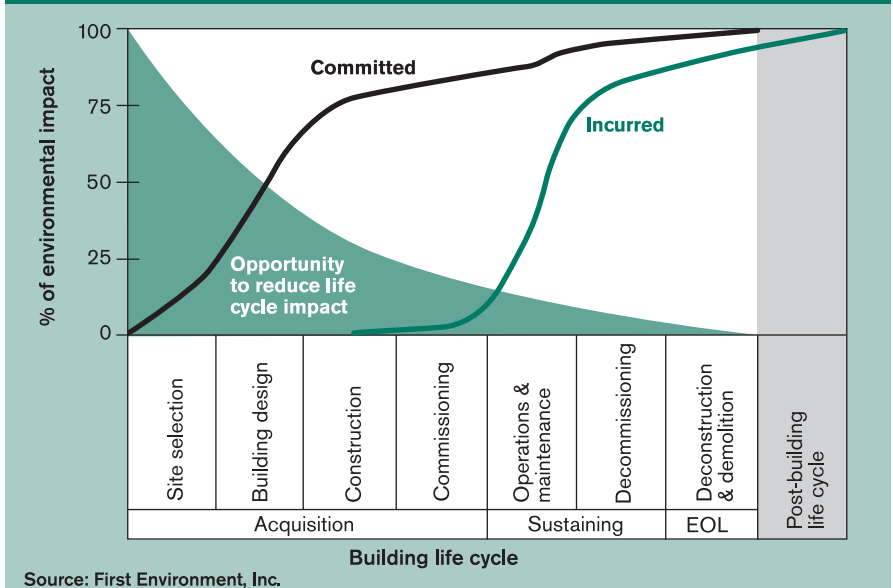
Standards and rating systems prescribe practices for reducing the environmental impact of buildings and some certify buildings meeting these standards. Some green building standards and rating systems are based on general guiding principles—for example, giving preference to recycled material. Other rating systems take a more comprehensive approach, using a more holistic life cycle framework. For example, the United Kingdom’s Building Research Establishment Environmental Assessment Method (BREEAM) rating system uses LCA-based materials credits. The Green Globes assessment protocol awards points for using LCA. The U.S. Green Building Council is studying approaches for incorporating LCA into its LEED green building rating system. In general, building standards and rating systems require little or no expertise in life cycle assessment to be useful to building professionals.

2. Tools for Evaluating Building Materials and Components

LCA databases and software have been developed to help building professionals select building materials and components. Results of life cycle studies are embedded in the tool, allowing building professionals to readily compare the life cycle impact of different materials and components. This information can be used to guide material and component specification and procurement.

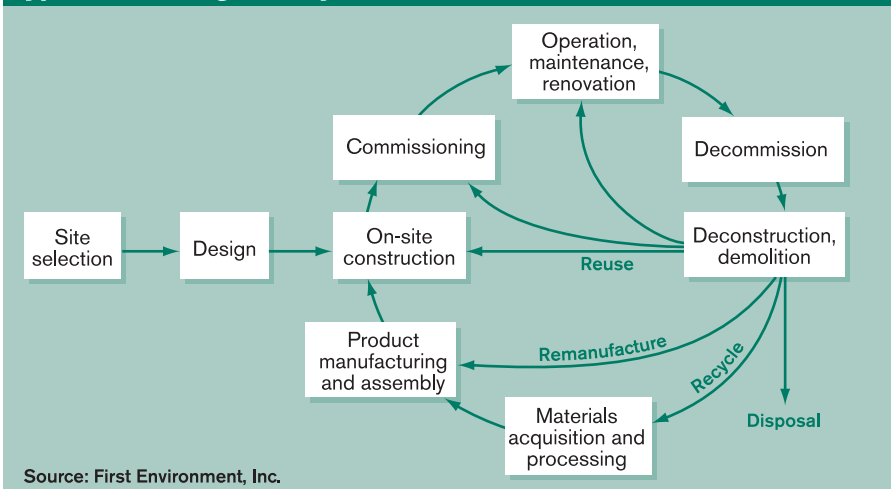
The National Institute of Standards & Technology’s (NIST) Building for Environmental and Economic (BEES) software is one of the most widely used material and product oriented LCA tools available to Building Teams. It is a publicly available Windows-based decision support software that enables designers and builders to evaluate the environmental and economic performance of several hundred building products. Among the categories of products found in BEES are framing, exterior wall finishes, wall sheathing, wall and attic insulation, roof coverings, interior wall finishes, floor coverings, slab on grade, beams, and parking lot paving. The key benefit of using software such as BEES is that users don’t need to know the intricacies of conducting LCA studies and very little time is required to evaluate the material or product of interest.

Hypothetical Comparison of Committed Versus Incurred Environmental Impact



Source: First Environment, Inc.

Typical Building Life Cycle



Source: First Environment, Inc.

Building professionals may want to use material- and component-focused tools embedded with LCA data when they wish to:

- Compare the environmental implications of different materials or components for a defined building application.
- Select environmentally preferable materials or components.
- Identify cost-effective green materials and products.
- Assess the range of options of building materials for a defined building application

Another important resource for obtaining high-

quality, consistent LCI data is US LCI database, which is managed by the High Performance Buildings Initiative at the U.S. Department of Energy's National Renewable Energy Laboratory. This database contains U.S.-specific data for building and construction products, as well as other products and technologies. All building products contained in the next version of BEES, due to be released in June 2006, will be included in the U.S. LCI Database. Databases such as the US LCI Database, used on its own or implemented in software like BEES, strive to provide high levels of data quality and consistency in analysis methods so that Building Teams can compare various building products fairly using life cycle assessment.

3. Software for Evaluating Whole Buildings

Evaluating the environmental implications of individual building materials and products becomes more complex when the goal is to evaluate or reduce the total environmental impact of a specific building during its lifespan. The choice of a specific building material, component, or system often influences other design decisions. For example, selecting either a wood, steel, or concrete structural system affects the extent and type of insulating material that can be used. Overall building performance depends on the interactions between individual components and subsystems as well as interactions with the occupants and the natural environment.

Several software tools seek to assess overall building design. Like the material and component LCA tools described above, whole building LCA tools use embedded life cycle inventory data for individual building materials and components, but they go one step further, taking a more holistic and integrated design approach that assesses how different building components, assemblies, and subsystems interact with each other to impact overall building performance.

One such tool is the Athena Institute's Environmental Impact Estimator, which can be used to assess the environmental implications of industrial, institutional, office, multiunit, and single-family residential designs. The Athena EIE can simulate over 1000 different building assembly combinations. Other whole building LCA tools include Envest from the U.K.'s Building Research Establishment and EcoQuantum from IVAM in the Netherlands.

The level of LCA knowledge and time required to use whole building LCA tools varies. Building Teams may find these tools useful when they want to:

- Develop a comprehensive environmental life

cycle model of a building design.

- Compare the environmental impacts of different building designs.
- Evaluate how substituting different materials or components in a building design affects its overall environmental impact.

4. General LCA Software

Commercial life cycle assessment software (such as SimaPro, GaBi, Umberto, and TEAM) can be used to conduct a comprehensive LCA of specific building materials and components or of specific building systems. These programs include extensive LCI databases that are not restricted to building products, provide an interface for modeling additional product life cycles, and analyze and report the life cycle environmental impact of modeled products.

General LCA software gives users more control over the life cycle inventory data, underlying assumptions, model development, and impact assessment. For example, such LCA software could be used to generate a detailed model of a specific building, assess its overall environmental impact, and evaluate an almost infinite number of material and component substitutions and design alternatives.

General LCA software requires a level of expertise that usually exceeds that of most building professionals, which means internal LCA expertise must be developed or a consultant must be hired. The software itself must be purchased, along with fees for annual data updates. In addition, collecting original life cycle inventory data can be time-consuming and expensive.

Selecting an Appropriate Tool

The four different types of tools for incorporating LCA into building require different levels of LCA knowledge, ranging from no LCA background to highly specialized LCA expertise. Each tool provides a different level of decision support, ranging from general prescriptions for reducing the environmental impact of buildings to detailed analysis of a specific building design.

The appropriate tool depends on the specific environmental objectives of the project. In general, building standards and rating systems are used to obtain green building certification and labels, material and component LCA tools are used to select and procure environmentally preferable building materials and components, whole building LCA software is used to model and evaluate whole building designs, and general LCA software is used to conduct detailed LCAs of specific building materials, components, and designs.