New Tools Assist in Designing for Sustainability

(This is part one of a four-part series)

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Some previous design strategies for making projects more sustainable included sourcing building materials locally, reducing the volatile organic compounds in a material, or increasing the recycled content. Although those strategies are good, with our increasing understanding of sustainability, designers are realizing that there are often trade-offs with such single-attribute criteria. For example, choosing a material that contains a large percentage of recycled content may result in a material that also has a very high embodied energy. Another example would be selecting a less durable material, which does not provide the resiliency or long-term performance demanded by today's high-performance structures. Hence, this may result in a structures premature replacement or higher ongoing maintenance.

Life-cycle assessment (LCA) is moving into the mainstream as designers look for ways to better assess the sustainability of their design choices and make fair comparisons between materials or systems. As we embrace this next step in our understanding and application of sustainability to our projects, it is important to better understand LCA.

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What IS LCA?

LCA is a comprehensive method used to assess and quantify the environmental impact of a product or process over its entire life cycle. LCA can be performed on a small product (like a pencil), a large product (like a building), or a process (such as the process for manufacturing a car).

Although LCA studies can be performed with a more-limited scope or time scale, the most representative accounting of a product's environmental impact includes all environmental flows over the full life of the product. Environmental flows are material and energy resources that go into a product, as well as all emissions to air, water, and land that result from its manufacture and use. An LCA over the full life cycle of a product—from extracting raw materials from nature, any transformation or manufacturing of these raw materials into a product, the product use, and end-of-life scenarios such as recycling or disposal—is considered a cradle-to-grave study.

Manufacturers commonly perform cradle-to-gate LCAs for products that are sold to a customer without knowing the intended, final use of the product. This allows the product manufacturer to identify environmental hot-spots in its process.

No matter the product being studied, an LCA involves handling and tracking data related to materials, water, and energy use, as well as emissions to air, water, and land (typically in the form of waste). For more complex products or processes, LCAs can become quite time consuming as they require large quantities of data to be analyzed. Computer models are available to assist with the data compilation and assignment of environmental impacts.

Regarding the standardization of LCA, the International Organization for Standardization (ISO) standards ISO 14040:2006[1] and 14044:2006[2] specify requirements and provide guidelines for performing LCAs. The procedures presented in ISO 14040 and ISO 14044 are generally scientific, transparent, and repeatable. Requirements in ISO 14040 and ISO 14044 relate to the four iterative stages of an LCA:

- Definition of the goal and scope of the LCA
- Life-cycle inventory (LCI)
- Life-cycle impact assessment (LCIA)
- Life-cycle interpretation, which includes reporting and critical review of the LCA, limitations of the LCA, relationship between the LCA phases, and conditions for use of value choices and optional elements

Because LCA is iterative, information gathered in a latter phase can cause effects in a former phase, which can result in the former phase needing to be reviewed and revised.

Beware the Boundary

When comparing results of one LCA to another, it is important to carefully examine the system boundary used for each LCA. ISO 14044 allows the LCA practitioner to consider any boundary, and include or exclude any process, as long as these items are all explained in the LCA report. It is during the goal and scope phase that inputs and outputs to the boundary are selected. To truly understand the full environmental impact of a product or process requires consideration of all the environmental flows from cradle to grave. This is a common approach.

What is Relevant?

It is easy to forget when studying an LCA report that there were a significant number of assumptions made for that study. It is important to understand these assumptions to put the results in the correct context. Often times, data are presented with many decimal places, implying that all digits are significant, which is typically not the case. In fact, most data values can be truncated to two significant figures without any loss of accuracy. Although LCA is a good tool, and arguably the best tool we have, it is not perfect.

LCA practitioners understand that there is inherent variability within the data. When comparing results of different LCAs, the differences in some of the environmental impact categories might be quite small. But a small change in a small number may result in a large percentage shift. Therefore, if results are presented as a percentage, it's important to look at the absolute differences in values, and beware of the coefficient of variation within the data. The percent difference in values among data sets may be smaller than the coefficient of variation among the data, thus the difference is insignificant.

Full Set of Impacts, Whole Life Cycle

Another new tool that designers are using to assess the sustainability of products is an environmental product declaration (EPD). EPDs are better than single-attribute criterion for assessing the sustainability of a product because they are LCA-based, but it is important to realize that EPDs can be prepared with a limited life cycle. There are two primary types of EPDs: business-to-business (B-to-B) and business-to-consumer (B-to-C).

B-to-B EPDs are frequently created for those products that are created without knowing how the product will be used during the life cycle. Think of a unit volume of concrete. One can create an EPD for a unit volume of concrete that takes into account all the energy, materials, and emissions related to the manufacture of the concrete. However, there are infinite possibilities for the use of that concrete once it leaves the plant gate. It could be used as a sidewalk, in a wall, as a bridge component, as a pavement, or many other applications. An EPD for a product like concrete or steel is typically in a B-to-B format. It accounts for all the environmental impacts from the cradle to the gate, but it does not include environmental impacts related to the use phase. Thus, B-to-B EPDs should not be used for comparisons among products.

B-to-C EPDs, alternatively, do account for all the environmental impacts for the full life cycle. These types of EPDs are typically created for products that have a known use in a building context. Think of products like carpet, windows, or doors. It is much easier to model the full LCA of these products because it is known how these products will be used in the structure.

New Tools, More to Learn

Designers are getting more sophisticated in their understanding of environmental impacts and sustainable design. Tools that assist in that understanding, such as LCA and EPDs, are robust but complicated, thus it is important to understand them fully. This article has shown that LCA and EPDs can show different results depending on the system boundary chosen, the quality of the data, and the timeframe selected for comparisons. Thus, the best way to evaluate the full environmental impact of a product is through a cradle-to-grave, ISO-compliant LCA.

References

1. International Standards Organization (ISO). 2006. Environmental management—Life cycle assessment—Principles and framework. ISO 14040, ISO, Geneva, Switzerland.
2. ISO. 2006. Environmental management—Life cycle assessment—Requirements and guidelines. ISO 14044, ISO, Geneva, Switzerland.

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