Whole-Building LCAs: MORE THAN Meets the Eye

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Proceed with caution, patience and an open mind.

WHOLE-BUILDING LIFE CYCLE ASSESSMENTS (LCAs) continue to be a major topic of discussion among design professionals committed to lowering the environmental impacts of the built environment.

Their performance is currently included in USGBC's LEED V4 program, ASHRAE 189-1—*Standard for the Design of High-Performance Green Buildings*, the *International Green Construction Code* (IgCC) and other green building rating systems.

A whole-building LCA is seen as a means of providing an objective comparison between two building alternatives with a goal of selecting the building alternative that will result in the least impact on environment. It is a multi-attribute evaluation of a variety of different environmental impact categories and is commonly contrasted to the selection of building products and materials based on a single attribute such as recycled, regional or bio-based content.

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While the goal of the whole-building LCA is noble, the process of conducting one is far from being simple and straight forward. The LCA novice mistakenly believes that all that is needed to conduct a LCA comparison is a schematic design of building, a list of the environmental impacts associated with all of the materials that will be used in the building and a simple drop-in-the-numbers estimation tool to create a legitimate building comparison. Pushing a "smart" button and receiving a list of comparative environmental impacts for two building alternatives is not possible. In fact, nothing could be further from the truth.

Meaningful Data

In order to conduct a meaningful whole-building LCA, certain key questions must be answered:

- What portions of the building are to be considered in the analysis?
- How are the building alternatives selected?
- What is the basis of comparison between the two building alternatives—materials or design?
- At what stage of design should the comparison be performed?
- How will the quantity of materials used in the two alternative building designs be determined?
- How accurate are the material quantities being used?
- Is operating energy to be included in the evaluation?
- What was the scope of the collection of the impact inventories?
- Are all product inventories consistently using the same scope?

- ➤ What methodology and assumptions were used in determining the environmental impact inventories for each product or material?
- ➤ What is the veracity of the environmental impact inventories used for each material or product?
- ➤ What environmental impact categories will be evaluated?
- ➤ What level of environmental improvement is desired for each category?
- ➤ What level of environmental detriment will be tolerated in each category?
- ➤ How will impact categories be prioritized against one another?

ASTM E2921-13—*Standard Practice of Minimum Criteria for Comparing Whole Building Life Cycle Assessments for Use with Building Codes and Rating Systems* defines the portions of the building under consideration to be "the complete building enclosure, structural systems, interior walls and interior finishes and trim of a building, which may include operating energy, but excludes furniture and attached cabinetry." Cleary this is much more than simply comparing a structural steel framing system to a concrete framing system. A whole-building LCA is just that—an LCA of the *whole building*—with all of the building products and materials taken into account. Yet at the same time, certain electrical, mechanical, plumbing, fire control and conveyance systems are not to be included because their selection should be governed by efficiency rather than material impacts.

The two building designs to be compared must be able to satisfy the same design program and be of the same location, orientation, size and function. Does this mean that the designer must design a second building to the same level of detail as the first design? Or can a simplified reference building be used? Or can an existing building satisfying the same function in the same area be scaled to match the first design? Or can the designer simply take the first building and start to substitute materials and—steel for wood, glass for brick, precast plank for reinforced concrete—adjusting the design for each change? While the answer is often debated, the fact is that unless an actual design of an alternative building is undertaken, the comparison of environmental impacts will not be accurate.

Product or Design

This brings up an even more important philosophical question: If a whole-building LCA is to be integrated into the design process of a building, should it be focused on product substitution or design enhancement? Is the goal to compare a concrete structure to a wood structure? Or is the goal to select the products that best fit the design program of the project and then optimize the use of those materials for an environmental perspective through an iterative design process?

Interestingly, many studies have been performed that compare structural steel-framed buildings to similar concrete-framed buildings that show there is little difference in the embodied environmental impacts between the two buildings. Why? Because of the fact that there is a great deal of concrete in a steel-framed building and a great deal of steel in a concrete-framed building. By comparison, optimization and the use of innovative structural systems can often reduce the amount of materials and the environmental impacts associated with those materials by 10% to 20%. Today, the real opportunity for verifiable environmental improvement is best focused on design improvements rather than material selection.

And at what stage of the design should the comparison be made? Conceptual? Schematic? Design development? Construction drawings? Clearly, the greater the level of design detail, the greater level of accuracy in the comparison. Today, some individuals with little background in LCAs are attempting to perform whole-building LCAs at a conceptual level. Material and product quantities at the conceptual level are, at best, ±20%, with some simplified tools yielding results when compared to actual design quantities that vary by as much as 50%—yet decisions regarding framing materials are being made based on a 5% improvement in environmental impacts.

In addition, many of these whole-building LCAs are being based on parametric estimates of material quantities without any structural design work being performed. The quantity of ceiling or floor coverings may be able to be calculated on a per-square-foot basis from an architect's conceptual plan, but the quantities of structural material required to meet the span and load requirements of the structure can't be accurately estimated on this basis. Those estimates must be developed by a licensed design professional competent in the practice of structural engineering if they are to have any basis in reality.

Half of the Story

But consider that the material quantities used in the comparison are only half of the necessary data upon which the calculations are to be performed. The other half is the values associated with the inventory of the environmental impacts of the product. But not all product manufacturers and material producers report their environmental impacts using the same scope. Some report cradle-to-producer-gate impacts (basically, the material produc-

tion process), some report cradle-to-manufacturer-gate impacts (e.g., impacts that would include the structural steel fabrication process), some report cradle-to-building (includes construction and installation), others report cradle-through-operation and still others report cradle-to-cradle (including deconstruction and recycling/reuse or landfilling). Which is correct? They all are. The challenge is that any whole-building LCA must ensure that all comparisons are being performed using data for all materials and products that are consistent with respect to the scope of the inventory of environmental impacts.

Not only do they need to reflect the same scope, but they also need to be based on the same methodology of calculating the impacts. Are the future uses of byproducts considered? Is credit given for future recycling? How is sequestering of carbon treated? Is the electric grid viewed from a national or regional grid perspective?

And how accurate are the results that are being published and available for use? Are they third-party reviewed? Have they been challenged at a technical level? Are the assumptions used in their determination clearly delineated?

Also, what environmental impact categories are being evaluated? Many whole-building LCA program requirements list six impact categories: global warming, ozone depletion, acidification, eutrophication, smog potential and primary energy use. Yet these are not the only six impact categories. A variety of lists exist detailing environmental impact categories, some with as many as 25 categories. A comprehensive whole-building LCA should report all of these categories if it is truly attempting to be a multi-attribute evaluation of comparative products. Clearly, impacts such as toxicity, resource depletion, land use and water use are critical for inclusion beyond the "Big 6."

From there, how do you determine which are most important? Which need to show the greatest reductions in impacts? That's debatable. Some of these impacts are global in nature (global warming, ozone depletion, human health, land use) while others are more regional (smog potential, eutrophication, water use). Some programs require a 20% reduction in a minimum of three categories, one of which must be global warming potential. Other programs look for a 5% improvement in two categories. There is little consistency, not to mention the ridiculousness of attempting to justify a 5% improvement in an impact category when the base data may be off by 20%.

And the flip side is that when product or material substitution occurs, some impact categories show improvement while others show degradation. How much degradation in one category is permissible to justify improvement in another? Should the designer be willing to accept an increase in eutrophication impacts in Los Angeles in exchange for a decrease in smog potential and water use? While a designer in Chicago might be willing to sacrifice water use and smog potential for a decrease in eutrophication? The answer to both questions is probably "Yes."

Valuable Metrics

So are whole-building LCAs an unworkable idea that needs to be abandoned? No, certainly not. Whole-building LCAs do provide a needed metric for the evaluation of the environmental impacts associated with buildings.

But with all of the issues noted above, aren't they too complex and expensive for a project in today's marketplace? Yes, regretfully they are. But it won't always be that way. The study of whole-building LCAs is a growing specialty field that will develop a pool of qualified practitioners skilled in the LCA process. But until then, caution must be exercised in the use of whole-building LCAs.

Recommendations for the use of whole-building LCAs in today's marketplace include the following:

- While simplified tools that estimate environmental impacts may be interesting to play with, they should not be relied upon to accurately determine the relative environmental impacts of two alternative building designs.
- Any whole-building LCA comparison must be based on structural quantities determined by a licensed design professional competent in the practice of structural engineering.
- Just as a competent structural engineer should be determining material quantities, a competent professional skilled and experienced in the performance of whole-building LCAs should be performing the LCA. The LCA task should not be assigned to a member of the design team unskilled in the use and interpretation of LCAs.
- At this point in the evolution of whole-building LCAs, the comparison of iterative designs using similar products and materials is much more instructive, reliable and worthwhile than attempting to compare buildings with dissimilar materials and products.

- Evaluation of a building's operating energy is best performed outside of the LCA by energy professionals using tools specifically designed for that level of analysis.
- Material producers and product manufacturers should be encouraged to publish environmental impact inventories for their products that clearly delineate the scope and methodology used to determine those impacts.
- Any comparison of materials, products or combinations of materials and products into assemblies and/or the whole building should only be performed when all products and materials are using consistent scopes and methodologies.
- Rather than rely on a cookbook approach to determining the relative importance of increases and decreases in environmental impacts, the design team should evaluate a broad range of impacts in the context of global, regional and local priorities.

Whole-building LCAs cannot be reduced to the pushing to a pushing of a "smart" button by an individual not trained in the nuances of LCAs. They are a valuable tool in improving the environmental performance of buildings, but only if they are based on reliable, consistent data and performed by qualified, experienced professionals. ■