Integrating LCA Tools in Green Building Rating Systems

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1. INTRODUCTION

Green building rating and certification systems are intended to foster more sustainable building design, construction and operations by promoting and making possible a better integration of environmental concerns with cost and other traditional decision criteria. Different building assessment systems approach this task from somewhat different perspectives, but they have certain elements in common. Most, if not all, deal in one way or another with site selection criteria, the efficient use of energy and water resources during building operations, waste management during construction and operations, indoor environmental quality, demands for transportation services, and the selection of environmentally preferable materials. And they do an admirable job of fostering and facilitating integrated design practices and a holistic approach. In short, the systems generally capture the complicated, web-like relationship between a building's construction and operations and its impacts on human health and the environment, a relationship that is similar to the complexity of ecological systems in nature where nothing functions or changes without resonating in another part of the system.

But there tends to be a disconnect between broad understanding of this relationship and the specifics intended to foster appropriate decisions. In a sense, there is an absence of a clear objective function, or at least a failure to always have the objective function in the forefront. The ultimate objective from an environmental perspective is to minimize the flows from and to nature: the use of natural resources of all kinds and emissions to air, land and water throughout a building's complete life cycle. Until we know much more at a hard scientific level, it is difficult to conceive any more sensible route to environmental sustainability.

The failure to maintain a clear objective function in building assessment systems is most notable in the case of material selection criteria and, to a lesser extent, in the energy use criteria. In fact, defining "sustainable materials" and encouraging their use seems to be one of the biggest challenges for the developers of green building rating systems. We believe that

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[1] ATHENA™ is a registered trademark of the ATHENA™ Sustainable Materials Institute. For the sake of simplicity, the trademark designation is not used throughout this document, but it is assumed to apply wherever the name ATHENA is used.

challenge must ultimately be met by a better integration of life cycle assessment (LCA) techniques and LCA-based decision support tools in whole building rating and certification systems.

This paper focuses on how we might accomplish that end. It includes a more detailed examination of the problem with reference to the different approaches of GBTool and LEED™[2], which tend to define the ends of the spectrum of possible approaches, a discussion of the role for LCA and ways to accomplish the integration, and a brief discussion of key constraints that must still be addressed and overcome.

2. THE PROBLEM

The problem is most easily understood in the context of the credits or scores assigned in rating systems for building material choices. It arises because material credits have typically evolved from a consensus-based understanding of environmental issues, understandings that, in some cases, have taken on an aura of conventional environmental wisdom that does not always stand up to objective analysis. As well, there is a risk of confusing means and ends, with the means becoming objectives in their own right to the possible detriment of environmental performance.

A couple of examples from LEED make the problem clear. LEED offers substantial credit for the use of recycled materials, the presumption being that recycled materials will automatically result in reduced environmental burdens. However, this may not always be the case, and recycling in any given situation may be good or bad. For example, recycling can save landfill space, but the process of recycling a given product may take more energy and adversely affect air quality more profoundly than would production from virgin resources. The focus on recycling ignores this possibility and implicitly gives more weight to solid waste and resource depletion issues than to global warming or other measures. The point is not that one issue or indicator is more important than the other, but that commonly held beliefs or assumptions appear to take precedence over data and facts in the decision process. In fact, recycling is probably the best example of a confusion of ends with means. Recycling has always been only a means to the objective of reduced flows from and to nature, but over time it has taken on the mantle of an objective in its own right.

A somewhat more subtle example is the LEED credit for the use of rapidly renewable materials. The stated intent of that credit is to, "reduce the use and depletion of finite raw, and long cycle renewable materials by replacing them with rapidly renewable materials." Rapidly renewable is defined as a rotation period of less than 10 years. Among a number of problems with a credit like this, is the fact that it ignores the value of land as a finite resource as well as the implications of all of the fertilizers, pesticides, insecticides, etc., that may be used in the process of producing rapidly renewable materials. Nor is there any a priori scientific reason for preferring a short cycle renewable over a long cycle renewable, let alone an arbitrary 10 year rotation over a 12, 15 or 20 year rotation.

[2]LEED™ is a registered trademark of the US Green Building Council. LEED stands for Leadership in Energy and Environmental Design. For the sake of simplicity, the trademark designation is not used throughout this paper but it is assumed to apply wherever the acronym LEED is used.

Similar kinds of problems arise even with the most sacred of rating system credits, those for operating energy use. Not all energy is equal: combustion emissions differ by energy form, and the upstream, pre-combustion implications of producing and moving different energy forms can be even more significant. As a result, a credit system that promotes minimal energy use without regard for the form of that energy may be misleading, especially if it results in the use of materials or construction techniques that have significant resource use or emission implications in their own right.

An argument often advanced to support giving precedence to the minimization of operating energy irrespective of material use implications is that operating energy use dominates the total of operating plus embodied energy. While this is generally true, the argument ignores other potentially serious environmental implications of too narrow a focus on operating energy. For example, toxic releases to water are more likely to result from the production of building materials than from building operations, and we must therefore cast our net wide enough to catch a full range of potential effects.

These are complex issues, and there is a danger in over-simplifying in a short conference paper. One of the complications worth noting here, for instance, is the potential for conflict between stewardship reasons for a specific credit and the realities of specific industries. For example, the recycling credit is relatively easy to achieve by the use of steel construction systems and might therefore promote more use of that material. But it is unlikely to promote more recycling because recycling is already a fundamental part of that industry's structure and operations, and is driven primarily by industry economics.

Before leaving this section, we must point out that the LEED Materials and Resources Technical Advisory Group (TAG) has already identified problems of the kind discussed here, and has wrestled with how they might be resolved in future versions of the system.

3. THE USE OF LIFE CYCLE ASSESSMENT METHODS

The LEED TAG has considered various methods to add importance and weight to matters such as durability, expected life of a building, reusability, and so forth. One recommendation has been to develop a matrix that would integrate such objectives with the amount of product or material in a building, with a variable outcome based on project inputs. The TAG has also discussed the potential role for LCA, which would be roughly approximated by the matrix approach. LCA is also the direction that has already been at least partially adopted in GBTool.

3.1 LCA Defined

LCA is a methodology for assessing the environmental performance of a service, process, or product, including a building, over its entire life cycle. Although the technique is still maturing, especially the aspects dealing with ultimate impacts on human and ecosystem health, it has become the recognized international approach to assessing the comparative environmental merits of products or processes. We cannot go into the details of LCA here, but the basic methodology for the various steps— goal and scope definition, inventory analysis, impact assessment, and interpretation — is set out in the ISO 14000 series of standards. The steps of most concern here are the life cycle inventory analysis (LCI) and the initial stages of impact assessment.

An LCI involves detailed tracking of all the flows in and out of the system of interest — 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.

The LCI data can then be characterized in terms of impact potentials (e.g., global warming, ozone depletion, etc.) and included in a series of measures called mid-point indicators. While the indicators do not answer the question of ultimate environmental impacts, they do provide a convenient way to summarize and compare the masses of inventory data, and at least make decisions on the basis of whether an alternative is likely to result in a reduction of flows from and to nature. The jury is still out on the best means of bringing mid-point indicators together in an assessment of ultimate, or end-point, impacts.

3.2 LCA-Based Decision Support Tools

There are already several LCA-based building-oriented decision support tools in use or under development in various parts of the world, for example Envest in the UK, EcoQuantum in the Netherlands, and ATHENA in North America. Although they use different modeling approaches and are regionally-specific, all of these tools work at the level of whole buildings and use embedded LCI data to develop mid-point indicators of the environmental implications of design alternatives.

Table 1 shows an example of the summary output from ATHENA for a recent study of an 18 storey office tower, with five levels of underground parking, designed using a conventional reinforced concrete structure with a curtain wall exterior cladding system.

Table 1 Summary of total life cycle embodied effects by major building component from office building LCA using ATHENA.

Building Components	Embodied Energy (Gj)	Solid Wastes (tonnes)	Air Pollution (index)	Water Pollution (index)	GWP (Equivalent CO_2tonnes)	Weighted Resource Use (tonnes)
Structure	52,432	3,273	859.0	147.0	13,701	34,098
Cladding	17,187	281	649.8	24.7	5,727	2,195
Roofing	3,435	145	64.8	5.8	701	1,408
Total	73,054	3,554	1,573.6	177.5	20,129	37,701
Per m^2	2.36	0.11	.05	.006	.65	1.21

Notes: The air and water pollution indices are based on the critical volume measure (method). GWP is global warming potential. Energy and emission estimates do not include operating energy.

The results in Table 1 are for the complete building life cycle including maintenance and replacement of materials, demolition, and transport to land fill of materials not likely to be reused or recycled. However, as indicated in the table notes, the results exclude operating energy and cover only the embodied effects. They nevertheless provide a good picture of a full range of environmental effects that result from the specific design and material choices made for the building under study. Those effects could readily be compared to alternative designs to select the one that provides the best performance, with best determined by an implicit or explicit weighting of the issues. We should note that the inventory results contained in the model would allow the calculation of other measures such as ozone depletion or acidification.

The key point with regard to this kind of analysis is that it encompasses a full range of estimated effects and goes beyond proxy measures like recycled content, or narrowly focused preferences like the preference for short- versus long-rotation renewables. For example, the estimates take account of recycled content in accordance with the ISO standards for various recycling situations, but they do so with full regard for the effects of the recycling process itself, including any related transportation.

Even if this approach does not cover all of the issues of concern in a building assessment, it establishes a much better basis for informed environmental choices and therefore for assessing the relative merits of a building from a materials use perspective. It is also important to note that, because this kind of assessment is at a whole building level, it takes into account the relationships inherent in a building system where the choice of one material for an application may dictate the use of other materials for thermal or other reasons.

3.3 The Use of LCA in Existing Assessment Systems

We have already noted the absence of LCA data in the LEED assessment system and the problems that can arise as a consequence. We should also look at GBTool, a more experimental system at the other end of the spectrum, where substantial advances have been made toward integrating LCA results.

GBTool accepts input data for a very broad range of materials as part of its basic structure. That data can be used in a tool like ATHENA to generate embodied energy and emission results of the kind shown in the previous sub-section. Those results are then returned to GBTool to generate a score that relates directly to material choices. This process has been followed by the Canadian Green Building Challenge team since the first round in 1998. GBTool also contains a relatively crude calculator for embodied effects, which draws on the same input data and is for use by those without access to ATHENA or an equivalent tool. The difficulty with that approach is the regional sensitivity of LCI data and the importance of undertaking such studies in a regional context.

Nevertheless, the crude calculator approach at least serves an educational purpose by giving users some insight into the environmental implications of their material choices. Other assessment systems like the Minnesota Design Guide and the Canadian BREEAM Green Leaf system also offer ‘educational’ credits for the use of ATHENA or an equivalent, an approach considered by the LEED materials committee for the next version of that system.

4. CONSTRAINTS

There are some key constraints to be overcome before LCA-based tools can be fully integrated in building assessment systems. Two, in particular, deserve emphasis: the problem of data availability, and the absence of appropriate references or benchmarks against which to judge LCA results for a particular building.

4.1 LCI Data Availability

LCI data is expensive and difficult to obtain, and is most often kept confidential by those manufacturers that do undertake studies. As well there is a problem of ensuring comparable data for different products or materials if the data is not generated by one organization, or at least by the use of a common protocol. However, this constraint is gradually being resolved through the creation of publicly available LCI databases in various countries.

In North America, for example, the U.S. LCI Database Project is a public/private research partnership dedicated to the creation of a publicly available LCI database of commonly used materials and processes. Manufacturers, researchers and the developers of tools or assessment systems will be able to call on the database to develop complete LCAs for specific processes, with reasonable assurance that the fundamental LCI data is sound and without having to redo LCI studies for common elements like energy production and basic transportation.

The ATHENA Institute undertook the first phase of the project in association with Franklin Associates, Ltd., and Sylvatica, with funding from several federal governments departments through the National Renewable Energy Laboratory (NREL). The data collection phase is now underway, and NREL has taken on the responsibility for long term dissemination, expansion and maintenance of the database.

An international project, the SETAC/UNEP initiative, is concurrently addressing issues related to data availability and comparability across international borders. As well, governments and research organizations in various countries are continuing to develop characterization and other impact assessment methods.

4.2 Judging significance

The development of appropriate references or benchmarks to judge the significance of LCA results is not so easily resolved. When a tool like ATHENA is used to provide LCA input to GBTool, the requisite reference cases have to be constructed and separately assessed for each building, a time consuming and expensive process. This has proved feasible within the context of the Green Challenge Process but probably would be unacceptable for a system like LEED that has to function in a commercial market. Even though the use of LCA tools may eventually result in reduced assessment costs, the reference constraint must first be overcome.

Ultimately, the answer is to develop case studies of different types of conventional buildings in different regions that can serve as benchmarks. That process is already underway in Canada and presumably in other countries with access to whole building LCA tools. But it is also time consuming and relatively expensive. And when the reference cases are developed, assessment system developers will have to determine how to score results for a specific building relative to the reference case(s). Not easy, but necessary.

5. CONCLUDING THOUGHTS

If a design team came forward with a building design that halved every number in Table 1, they would not receive a single point under the LEED system. We believe that must change. We must somehow overcome the reliance on often unsupported conventional wisdom, especially with regard to building materials, and focus instead on rewarding designs that truly result in reduced environmental burdens. Despite its limitations, LCA seems to offer the best potential for achieving that objective.

There are certainly constraints to be overcome, principally with regard to the availability of fundamental LCI data and the development of appropriate benchmarks for judging and rewarding environmental improvements. In the meantime, the developers of building rating and assessment systems can take positive steps by becoming more conversant with the principles and practice of LCA, and with the tools that are already available to help in the application of LCA. However, system developers must also exercise caution, and maintain a clear distinction between the apparent merits of individual materials or products and their use in a whole building context where they may function differently or have broader implications.

In the long run, the integration of LCA tools into whole building assessment systems will yield significant benefits, not only in improved understanding and crediting of environmental performance, but also in reduced assessment complexity and cost. The focus will have shifted away from conventional wisdom, and detailed documentation of related purchasing decisions, toward a more robust objective function — the minimization of life cycle flows from and to nature.