Understanding the Green Building Toolkit: Picking the Right Tool for the Job

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1. INTRODUCTION

The green building scene is characterized by clutter and confusion. Databases, tools, eco-organizations and eco-events vie for attention, while well-meaning advice and rules of thumb may or may not help to manage a generally complicated, difficult to understand scene. This paper aims to help bring some order to the chaos by introducing a simple tools classification system and establishing how tools, including LEED™, interrelate and where they fit in the green design process.

The paper then focuses on the materials selection aspect of designing, constructing and operating environmentally friendly buildings, a task that is especially complex, with few simple measures or rules of thumb to make the selection process easy. We are usually in the position of having to trade off desirable with not-so-desirable outcomes. Two complementary tools, BEES (Building for Environmental and Economic Sustainability) and the Athena Environmental Impact Estimator (EIE) have been designed to help with that process, providing the building community with ready access to the essential data and measures.

The paper provides an overview of the two tools, outlines how they complement each other, and discusses when they are best used by design teams during the project delivery process. In that context, the principle of functional equivalence is discussed as it relates to tool selection and product comparisons at any stage of the process.

Both BEES and the EIE provide users with access to data and results obtained through life cycle assessment (LCA), a methodology that is increasingly important for making decisions throughout the entire process, from conceptual through detailed design, specification and procurement. As background, it is useful to briefly explain LCA before introducing the simple classification system.

1.1 The LCA Background

Put simply, LCA is a methodology for assessing the environmental performance of a product over its full life cycle, often referred to as cradle-to-grave or cradle-to cradle analysis. Environmental performance is generally measured in terms of a wide range of potential effects, such as the following:

- fossil fuel depletion;
- other non-renewable resource use;

- water use;
- global warming potential;
- stratospheric ozone depletion;
- ground-level ozone (smog) creation;
- nutrification/eutrophication of water bodies;
- acidification and acid deposition (dry and wet); and
- toxic releases to air, water, and land.

All of these measures are indicators of the environmental loadings that can result from the manufacture, use and disposal of a product. The indicators do not directly address the ultimate human or ecosystem health effects, a much more difficult and uncertain task, but they do provide good measures of environmental performance, given that reducing any of these effects is a step in the right direction.

In LCA, 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. In the building community, the tendency is to refer primarily to 'embodied energy', but there is a wide range of embodied effects, as implied by the list of indicators. 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).

In the case of buildings, the energy required to operate a building over its life greatly overshadows the energy attributed to the products used in its construction. However, for other embodied effects such as toxic releases to water, effects during the resource extraction and manufacturing stages greatly outweigh any releases associated with building operations. The point is to beware of the common tendency to focus only on embodied energy. The essence of LCA is to cast the net wide and capture all of the relevant effects associated with a product or process over its full life cycle.

In that vein, it is also important to note that the LCA of a given product should take account of the production and use of other products required for cleaning or maintenance during its use phase. For example, we should take account of the paints required to maintain some types of wood cladding, and of the cleaning products required to maintain various kinds of flooring. We must similarly take account of the repair and replacement of products through their life cycle in a building application.

The final point to note about LCA is that it is not the same as life cycle costing (LCC). The two methodologies are complementary, but LCC focuses on the dollar costs of building and maintaining a structure over its life cycle, while LCA focuses on environmental performance. Performance is measured in the units appropriate to each emission type or effect category. For example, global warming gases are characterized in terms of their heat trapping effects compared to the effects of CO_2, and global warming potential is measured in equivalent tonnes of CO_2.

2. A TOOL CLASSIFICATION SYSTEM

This simple tool classification system helps position BEES, the Environmental Impact Estimator and other tools in terms of their focus, intent and use in various phases of a project delivery process. The system suggests three main levels of tools, labeled simply as Level 1, 2, and 3 tools.

Level 1 tools focus on individual products or simple assemblies (e.g., floor coverings or window assemblies) and are used to make comparisons in terms of environmental and/or economic criteria. These are probably the most common tools, with BEES and GreenSpec Directory especially relevant for architects. They are particularly relevant during the specification or procurement stage of project delivery when product-specific decisions are being made.

BEES is discussed in detail later. GreenSpec is a guide or directory to environmentally preferential building products produced by Building Green (the publishers of Environmental Building News) and provided in book form as well as through an on-line web site subscription.

One could argue that labeling systems such as Green Seal, the Environmental Choice program, and various forest certification systems are also Level 1 tools. The caution is that most labeling programs focus on single attributes, or performance measures (energy use or recycled content, for example). The product in question may indeed be excellent in terms of the criteria selected for the evaluation, but that does not necessarily mean it would score well in a system that takes more attributes into account.

Other Level 1 tools used in North America (e.g., SimaPro, TEAM, and GaBi) are intended more for the use of LCA practitioners and are therefore of less interest here.

Level 2 tools focus on the whole building, with each one typically providing decision support with regard to specific areas of concern such as operating energy and lighting simulation, life cycle costing, and life cycle environmental effects. These tools tend to be data-oriented and objective, and apply from the early conceptual through detailed design stages.

The Athena EIE tool fits in this category along with such tools as Energy Plus, Energy 10, and Radiance.

Level 3 tools are whole building assessment frameworks or systems that encompass a broader range of environmental, economic and social concerns or issues considered relevant to sustainability. They use a mix of objective and subjective inputs, leaning on Level 2 tools for much of the objective data — energy simulation results, for example. All use subjective scoring or weighting systems to distill the information and provide overall measures, and all can be used to inform or guide the design process.

Currently available Level 3 tools — the best known are probably LEED™ and BREEAM — may apply to new projects, to existing buildings, and to major renovations or retrofits. Some require external auditors, and most yield certificates or labels indicating a building's performance. They can be used for a wide range of building types.

2.1 Other Tools, Systems and Sources

The tools mentioned above are only representative and certainly do not exhaust the list for each category. For example, there are other sources of information on products, and there are excellent web sites that provide design guidance as well as specific technical information. There are also other whole building assessment systems used in the U. S. and elsewhere.

The point is to establish some clear and important distinctions. Does a tool work at the level of whole buildings or is it focused more on individual products or components? Does it deal with a specific topic or concern, like energy use, or does it cover a broad spectrum of sustainability issues? Is the tool quantitative or does it include subjective or qualitative elements? Too often these distinctions are ignored and comparisons are made between tools that are intended for entirely different purposes. BEES and the Athena EIE are complementary tools, intended to meet different needs at different stages in the project delivery process, not competitive tools between which one must choose.

3. A CLOSER LOOK AT BEES AND THE EIE

When faced with questions about the use of specific materials to achieve sustainability objectives, the answers are seldom as clear-cut as we would like. We would all welcome simple answers about which products are truly green, taking all factors into account over the whole life cycle. The unfortunate fact is that we can't get those answers without formal LCA or some equally thorough approach. Both BEES and the EIE provide that kind of information, but for different purposes and in different ways. This section provides a closer look at the two tools, what they do and how they do it. Section 4 then discusses the underlying intent or purpose of each in the design and delivery process. In that context, we address two very important issues: maintaining functional equivalence when making comparisons; and using brand-specific as opposed to generic data.

3.1 BEES

BEES is an LCA-based software tool developed by the U.S. National Institute of Standards and Technology (NIST), with support from the U.S. EPA Environmentally Preferable Purchasing Program. The NIST Building and Fire Research Laboratory developed the software to provide the building community with access to the data necessary for selecting cost-effective, environmentally preferable building products. BEES does this by allowing product-to-product comparisons based on LCA and LCC data, with the LCA data covering a full range of environmental flows from raw material acquisition through product disposal. The user interface is menu driven, with results provided in both graphical and tabular form.

An especially valuable feature of BEES is its ability to provide users with direct comparisons between environmental performance and life cycle costs, thereby making trade-offs explicit. The direct economic versus environmental comparison is just one of many ways in which a user can view side-by-side comparative results for different products. Results can also be viewed by life stage and by environmental flow (e.g., acidification flows include such substances as ammonia, hydrogen chloride, and sulfur oxides) for a list of 12 performance measures. In addition to most of the measures cited in Section 1.1, the BEES measures include criteria air pollutants, indoor air quality, ecological toxicity and human health.

All regional and local impacts are scored based on new U.S.-specific methods developed by the U.S. Environmental Protection Agency. The significance of a product's performance with respect to each impact is also included in the scoring using new U.S. EPA data that serves as a U.S. "yardstick" against which each impact can be scored. What this means is that BEES can now compare scores across most building elements (e.g., roof coverings and floor coverings) to see which elements get the poorest scores and thus would benefit most from environmental improvement.

BEES uses importance weights to combine environmental and economic performance measures in a single performance score, although the user can select a "no weighting" option. If weighting is selected, the user first decides how to weight environmental versus economic performance (e.g., 50/50 or 40/60), and then selects from among four alternative weighting systems for the environmental performance measures. The four alternatives include a user-defined option and equal weighting as well as two systems developed by scientific panels. Users can also change the default discount rate used for calculating the present value of life cycle costs.

BEES 3.0 includes approximately 200 building products or variations on products, including about 80 brand-specific products. For example, in the 'slab on grade' product category, there are 10 generic product variations and six brand-specific variations. In the case of floor coverings, there are 17 distinct generic products and 18 brand-specific products. The generic data covers the most representative production technology or an aggregated result based on U.S. average technology for the relevant industry. Brand-specific data was provided through the participation of a number of manufacturers in the "BEES Please" data program.

BEES is available for download free of charge from www.bfrl.nist.gov/oae/software/bees.html.

3.2 Athena EIE

The Environmental Impact Estimator software was developed by the non-profit Athena Institute to make it possible for architects, engineers and researchers to assess the environmental implications of industrial, institutional, office, and residential building designs at an early stage in the project delivery process. The EIE is also an LCA-based decision support tools focused at the level of whole buildings, or complete building assemblies (walls, floors and roofs, for example). It therefore captures the systems implications of product selections related to a building's structure and envelope.

The tool is regionalized — it currently covers eight specific regions for Canada, three for the U.S., and a U.S. average — and allows users to take account of the embodied effects of material maintenance and replacement over an assumed building life, distinguishing between owner-occupied and rental facilities where relevant. The building life is selected by the user and can be varied to assess relative durability effects.

If an energy simulation has been completed for a design, the estimated annual operating energy use by type can be entered through a simple dialogue; the EIE will then take account of operating energy emissions and pre-combustion effects (i.e., the energy and emissions associated with making and moving energy). It will also let the user compare life cycle embodied energy use to operating energy use.

The Estimator incorporates the Institute's life cycle inventory databases for generic products, covering more than 90 structural and envelope materials. It simulates over 1,000 different assembly combinations and is capable of modeling the structure and envelope systems for about 95% of the building stock in North America.

A conceptual building design is entered in the EIE using preset building assembly dialogues. The user can then instantly see the cradle-to-grave, region-specific implications of a design in terms of a detailed list of flows from and to nature (inventory results) as well as the following summary measures:

- embodied primary energy use;
- global warming potential;
- solid waste emissions;
- pollutants to air;
- pollutants to water; and
- natural resource use.

As design data is entered using the assembly dialogues, the software builds a tree to help track entries. The tree can also display, in value or percentage terms, any one of the above summary measures. This enables the user to track the effects of each assembly addition as it is made, or to quickly pinpoint which one is causing a particular environmental effect.

Results from an individual design can be seen in summary tables and graphs by assembly group and life cycle stage. Detailed tables and graphs show individual energy use by type or form of energy, and emissions by individual substance for both the assembly group and life cycle stage breakouts. A comparison dialogue can be used to make side-by-side comparisons of as many as five alternative designs, for any one or all of the summary measures. The comparisons can be among variations on a base case, or can include completely different projects. Similar projects with different floor areas can be compared on a unit floor area basis.

For more information, please visit the Institute's web site at www.athenaSMI.ca.

4. PICKING THE RIGHT TOOL

To understand how BEES and the EIE fit in a complementary suite of sustainable building tools, and where each is best used, we have to focus on the kinds of questions asked and the information needed at different stages in the project delivery process. We also have to be conscious of the difficulty of maintaining functional equivalence when making building material comparisons.

4.1 Maintaining Functional Equivalence

In LCA-based comparisons, we use the term 'functional equivalence' when referring to the problem of ensuring that two or more products provide the same level of service. Ensuring functional equivalence in product comparisons is not as easily accomplished in building applications as might be supposed. The problem is that the choice of one product may lead to, or even require, the choice of other products. Consider the following examples:

- the choice of wood, steel or concrete structural systems will likely influence, or even dictate, the choice of insulation materials;
- an above-grade structure using high mass materials may require more concrete in footings than a lighter structural system; and
- a rigid floor covering may require a different substrate than a flexible floor covering.

These are just three examples of situations where product comparisons should take account of other material-use implications of the alternatives. In other words, comparisons should be made in a building systems context rather than on a simple product-to-product basis. Even though two products may appear to be equivalent in terms of specific criteria like load bearing capacity, they may not be at all equivalent in the sense of true functional equivalence.

In a similar vein, we should be cautious to take account of all the components that may be required during building construction to make use of a product. Mortar and rebar go hand in hand with concrete blocks, just as fasteners, tape and drywall compound are integral to the use of gypsum wallboard, and nails are an essential component of a wood stud wall.

However, not all products pose a functional equivalence problem to the same degree. In general, product-to-product comparisons are more likely to be misleading when dealing with structure and envelope materials, where the systems context is key. As we move to interior finishes, fit-out products and furnishings, product-to-product comparisons are more realistic. For example, resilient or flexible floor coverings can readily be compared to each other as long as we take account of installation materials, cleaning products, expected service life, and what happens at the end of a product's life. Even window systems, although part of the envelope, are typically delivered to a construction site as pre-assembled components that can be compared to each other in terms of thermal performance or other criteria, and without too much regard for broader systems implications.

In short, we can think in terms of a continuum from very systems-oriented products at the structural end of the scale, to more stand-alone products at the interior fit-out end. The task is to exercise caution and judgment about whether any given comparison is legitimate.

4.2 Different Questions at Different Stages

Developers of tools like the Athena EIE are often criticized for not for not including brand- or supplier-specific data. The critics argue that supplier-specific data should be the ideal toward which we all strive. Certainly, there is no question that generic data may mask very important differences among suppliers. In fact, the best performer in one material category may be better than poorer performers in a competitive category, even though the generic averages might suggest otherwise. However, this does not automatically mean that brand-specific data is the ideal, nor is it necessarily even the right approach for all tools. Different tools are intended to address different types of questions at different stages in the process, and that in turn has a bearing on the kind of data that is best for each tool.

In the case of the EIE, for example, the 90 or so generic product databases are combined in hundreds of permutations and combinations related to different assembly possibilities in a building. Imagine the difficulty from the user's perspective (not to mention the software development and data management side) if each of the product groups had brand-specific alternatives. The value of the tool could be very quickly compromised because of the added complexity in terms of entering choices and understanding comparative results.

Perhaps even more important is the question of relevance. The EIE is intended for use at the conceptual design stage when significant environmental effects are often locked in by basic structure and envelope decisions. At that stage in the process, the designer makes critical and sometimes irreversible decisions and therefore has to have good information about the relative effects of materials, components or design alternatives at a generic level. Seldom is there concern at this stage about final product choices and sources. Indeed, many of the critical elements in conceptual design are in the nature of commodities with relatively low brand differentiation. We believe it is more important that environmental performance measures at this stage reflect consistent life cycle assessment data for the market array from which choices will ultimately be made.

In contrast, brand-specific information becomes much more important at the specification and procurement stages of project delivery. Indeed, this kind of data is essential for product categories where there is high differentiation in environmental performance. BEES is already meeting that need in a number of product categories, floor coverings for example, and can be expected to continuously expand to meet the need in other categories.

There is a risk that selection of the best environmental performer among competing suppliers at the procurement stage will not reinforce decisions made on the basis of industry averages at the conceptual stage. However, we consider that risk to be acceptable if BEES and the EIE concentrate on the product categories for which each is best suited. For the Athena EIE that means continuing to focus on the building structure and envelope materials, which tend to be more interrelated in a building systems context and can therefore pose functional equivalence problems if comparisons are not made on an assembly, if not whole building, level. For BEES, it means focusing on, and expanding in, the product categories where systems implications are non- existent or minimal, and where brand differentiation tends to be more significant.

5. IN CONCLUSION

Eventually, it may be possible for NIST and the Athena Institute to more closely link their databases, and even to create more direct linkages between the tools themselves. For now, they should be viewed as complementary Level 1 and 2 tools serving critical needs at different stages in the project delivery process. Both tools, and indeed other Level 1 and 2 tools, can serve as valuable inputs for the Level 3 tools, such as LEED™. Few debate the need for LEED™ to steadily become less prescriptive and more performance oriented, where performance is defined in terms of environmental impacts such as global warming potential or the other measures listed earlier. To get there requires good data and good tools, objectives that remain central for both NIST and the Athena Institute.