

Life Cycle Assessment and the LEED® Green Building Rating System™

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ABSTRACT

In response to concerns that its LEED Green Building Rating System places too little emphasis on material durability, the U.S. Green Building Council has begun to introduce life cycle assessment (LCA) into the program structure to give greater consideration to the longevity and performance of building components. Recently, a new LCA methodology called Eco-Efficiency Analysis has emerged that may be useful in addressing life cycle assessment within the current LEED program. This paper will review the basic concepts of eco-efficiency and the mechanics for conducting an eco-efficiency analysis of construction materials. Examples of roofing and other construction materials that have previously been analyzed and rated using this method will be reviewed, and the implications of the findings will be discussed.

SPEAKER

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INTRODUCTION: THE U.S. GREEN BUILDING COUNCIL AND LEED®

In less than two decades since its inception, the U.S. Green Building Council (USGBC) has become a significant force in the construction industry. In addition to sponsoring its annual Green-build convention, drawing thousands of attendees, the USGBC has achieved noteworthy success in the development and promotion of the LEED® (Leadership in Energy and Environmental Design) Green Building Rating System." In less than ten years following the formal introduction of this rating system, over 38,000 architects and building designers have received LEED-sponsored accreditation and over 3 billion square feet of building space throughout the world are claimed to be involved in the LEED program (USGBC, 2007). Given this impressive track record, the U.S. Green Building Council is well justified in calling LEED "a leading-edge system for designing, constructing, and certifying the world's greenest and best buildings." (USGBC, 2004.)

WHAT IS LEED?

According to the USGBC, LEED is a "voluntary, consensus-based, market-driven rating system designed to accelerate the development and implementation of green building practices." (USGBC, 2004.) LEED was created to define green building by a common standard of measurement, promote green design practices, stimulate competition, raise consumer awareness, and ulti-

mately transform the building market.

Instead of offering a complex definition of green building, LEED relies on a simple enumeration of its most-recognized characteristics. These key green characteristics include 1) sustainable building sites, 2) water efficiency, 3) energy conservation and atmospheric impact, 4) effective use of materials and resources, and 5) indoor environmental quality.

By combining these key attributes into a single standard, LEED helps to promote a holistic approach to building design. By developing a comprehensive rating and award system for these key attributes, LEED offers a stimulus for competitive responses to the challenge of green construction. And by promoting LEED as an easily recognized concept, the system builds consumer awareness about green construction, which in the long run will transform the way buildings are designed, constructed, and maintained. These three fundamental strategies – simple definition, competitive motivation, and brand awareness – appear to be propelling LEED along a path toward its final goal of transforming the building market.

ADVANTAGES OF LEED

Promoting the "Big Picture"

Because it offers a broad-based model addressing almost every element of building design and construction, LEED challenges the construction industry to consider a wide range of approaches to increase the overall

sustainability of buildings. When applying LEED to a construction project, the building owner and designer must deal with many important environmental issues, including site impact, water and energy conservation, material use and recycling, and indoor environmental quality. By engaging them in such a broad array of important issues, LEED rewards building owners and designers genuinely interested in increasing the sustainability of the built environment rather than minor tinkering with selected construction elements.

Keeping it Simple

LEED offers a simple and understandable model that can be implemented by a wide variety of building owners and construction professionals. While other systems may require either complicated computer models or elaborate assessment programs, LEED relies on a simple, consensus-based point system. First, LEED divides important environmental issues into five basic categories focusing on-site considerations, water conservation, energy savings, material properties, indoor environment, as well as a sixth category for innovative practices. Each category offers a specific number of credits of one or more points, each tied to important concepts within the category. A building project that earns 26 points can become "LEED Certified," while additional points can earn special Silver, Gold, or Platinum status.

Although the basic point system is very simple, LEED has integrated several features that

add sophistication to the model without adding significant complexity. First, in recognition that certain environmental considerations should be “non-negotiable” in sustainable building design, all five primary LEED categories contain prerequisites that must be met before points can be earned. As an example, certain minimum standards of energy efficiency must be met before any energy savings credits may be earned. Secondly, because some environmental issues may have greater potential impact than others, the LEED point system is weighted toward many of the more salient concepts. As an example, up to 10 credits can be earned for a variety of overall energy-saving practices regardless of the energy source, while only one credit can be earned specifically for energy initiatives associated with “Green Power.”

Fostering Competition

Beyond its simplicity and ease of application, the LEED point system also appeals to the competitive nature of society. Through its combination of an easy-to-understand point system and specific levels for attainment and recognition, LEED “...takes a complex, multifaceted problem... and makes it a game, with clearly established rules and intricate strategies...” (“White Paper on Sustainability,” 2003, p. 8). In addition to helping simplify a complex and important task, LEED also offers building owners and designers an opportunity for tangible recognition for their efforts in advancing sustainability. By challenging designers to look at sustainability in an integrated and accumulative manner, LEED helps the building team benchmark where they it wants to go and devises strategies to reach its objectives.

Building “Green” Awareness

The simplicity of the LEED program also appears to help it build awareness about the importance of sustainable construction. Its simplicity makes it easy to understand, easy to specify, and (relatively) easy to deliver. And the active promotion of LEED by the over 10,000 member organizations of the U.S. Green Building Council also appears to be building a special “brand” awareness about LEED itself. According to the editors of *Building Design & Construction*, “The LEED rating imbues projects with the equivalent of the Good Housekeeping seal of approval or a favorable review in *Consumer Reports*.” (“White Paper on Sustainability,” 2003, p. 11.)

LIMITATIONS OF LEED

Limited Reach

Since its inception in 2000, less than 160 million square feet of commercial buildings have been registered in the LEED program. As a result, LEED projects represent a very small percentage of total commercial building activity in the United States. According to a variety of industry sources, over one billion square feet of new non-residential buildings are commissioned every year. As a consequence, the 140 million square feet of LEED buildings registered since 2000 represent less than 2 percent of over 6 billion square feet of buildings erected nationwide during the same period.

Many advocates of LEED would respond that the visibility of the program has influenced millions and millions of square feet of construction not officially registered with LEED. But even if it is assumed that the LEED system influences many new construction projects beyond the official registration numbers, the impact of LEED on the commer-

cial roofing industry remains very small. The reason is very simple: Over 70% of all commercial roofing installations involve the re-roofing of an existing building rather than the installation of a roof on a new building. Even if every new building erected in the United States were LEED-registered, over two-thirds of commercial roofing activity would not fit into the LEED mold. It should be noted that the USGBC also has initiated a LEED program for existing buildings (LEED-EB). However, this program is designed to address major building renovations, which drive a very small portion of the three billion-plus square feet of annual re-roofing activity in the United States.

Potential for Confusion

For the roofing industry, the benefits of LEED's broad-based approach are offset to some degree by the difficulties encountered in identifying exactly which credits can be derived from roofing systems. Roofs serve a variety of functions within a building, shielding them from sun, wind, and rain, insulating them from external temperature fluctuations, directing water run-off, and providing a working platform for important mechanical equipment. Because of these many functions, potential environmental benefits of roofs can be found in every LEED category. In addition to material features such as surface reflectivity, recyclability, and hazardous content, roofing materials may be critical to credits related to responsible site development, water efficiency, energy consumption, and indoor environmental quality. As a result, “roofing credits” in LEED can be identified as part of at least a dozen different credit categories.

Given the increasing popularity of the LEED concept and the rating system's disjointed approach to roofing, the potential for

confusion may be significant, especially for a building owner or designer wanting to apply the LEED concept to the billions of square feet of re-roofing projects installed annually. This confusion is frequently manifested when roofing contractors or manufacturers are asked whether their roofing products are "LEED-compliant." Unfortunately, the answer to this question is "Yes, no, and maybe." "Yes," because some roofing products, by virtue of a specific characteristic (such as surface reflectivity), can gain a specific credit (in this case, for reducing solar heat absorption). "No," because some roofing products offer environmental features (such as increased longevity) that aren't currently measured by the LEED system. And "Maybe," because some roofing products can contribute to LEED only if and when the products are correctly integrated into a larger design strategy addressing a specific LEED credit.

Insufficient emphasis on durability

Without a doubt, the roofing industry's greatest concern regarding the LEED program is the apparent overemphasis on apparent environmental benefit without an equal concern for the durability of the products employed to achieve this environmental benefit. As an example, a building owner or designer can achieve one LEED point for painting the building roof with a reflective coating even though the coating may last less than five years. At the same time, no credit is available for the selection of a high-performance but non-reflective roofing system that may be designed and warranted to last 30 years or more. Unfortunately, LEED tends to favor highly reflective roofs as the sustainable choice even though many of these roofs use either temporary coatings or relatively new polymer

technologies to gain their apparent green benefits.

Although it is beyond the scope of this paper to discuss material durability in detail, one important principle appears to permeate the research record of the building envelope industry. With few if any exceptions, innovations in building envelope technology tend to experience a "learning curve" before the technology stabilizes and provides optimal performance. As an example, early versions of EPDM roofing systems exhibited significant problems relating to field seams and perimeter attachments. But today, EPDM is considered to be one of the most durable roofing systems available, and premium EPDM roofing systems now are available with warranties up to 30 years. Similar examples of this learning curve may be cited for every other major building envelope product. And beyond these specific examples, numerous studies of historical repair cost support the conclusion that the performance of any building envelope system tends to improve as the industry gains experience with that system (Hoff, 1997 and 2003; Schneider and Keenan, 1997).

The implications of this learning curve on building envelope sustainability are significant, especially since the current LEED program may tend to favor newer technologies that may not yet offer optimal performance in regard to durability. Although it would not be fair to label such technologies as "unproven," it may be justifiable to assume these products may still have a way to go in terms of their performance learning curves based on the evidences of historical performance data.

Unfortunately, the current LEED model makes little or no attempt to reconcile the need to meet new and emerging environ-

mental needs with the preponderance of evidence pointing toward the slow development of any new building envelope technology. In fact, it is interesting to note that the EPA Energy Star® roofing standard, which is incorporated into the LEED credit system, only requires Energy Star roofing materials to provide a portion of their initial benefit for up to three years and provide a minimum overall durability warranty equal to "comparable" non-reflective products. Because some of these "comparable" products may offer as little as a five- or ten-year warranty, many of these so-called sustainable products offer much less in terms of durability when compared to currently available high-performance roofing systems offering between 20- and 30-year warranties.

This concern about product durability and performance is shared by many other sectors within the construction industry. Kenneth Mentzer, president of the North American Insulation Manufacturers Association, articulates what is a common concern among many construction materials manufacturers and suppliers:

"With the green building movement still in its infancy, the construction industry is rushing to promote 'green' products with all the excitement that comes with building a new market. History shows us, however, that while we must move forward with innovation and excitement, we must also take care to be responsible market stewards. *'Green' products manufacturers should be careful to provide defensible proof that these products perform as stated.*" (White Paper on Sustainability," 2003, p. 13). *[Italics added.]*

Concerns about durability also appear to be shared by the majority of construction professionals who design, specify, and manage today's buildings. According to a recent *Building*

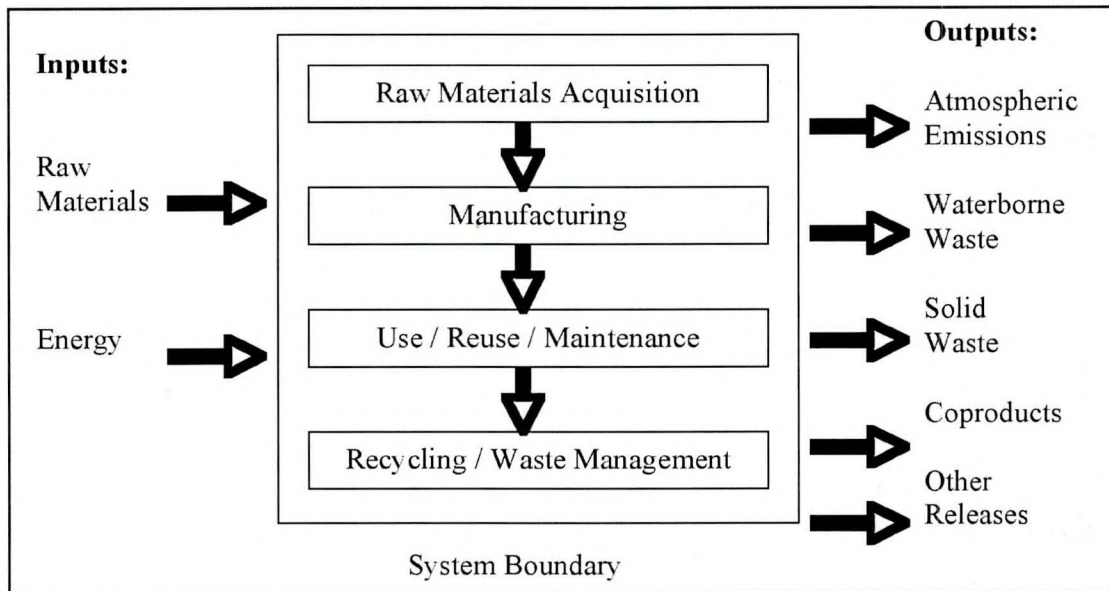


Figure 1 - Life cycle stages. (Source: Scientific Applications International Corporation, 2006, p. 1.)

Design & Construction survey of over 70,000 building designers and owners, the strongest opinion regarding sustainable construction was that building materials should be evaluated on the basis of life cycle cost, long-term durability, and maintenance, and not just environmental impact and energy savings ("White Paper on Sustainability," 2003, p. 17).

LIFE CYCLE ASSESSMENT AND THE ISSUE OF DURABILITY

What is Life-Cycle Assessment?

Before further discussion of USGBC's response to durability concerns can be undertaken, it is important to briefly discuss the history and of an emerging approach to measuring the sustainability of products: Life Cycle Assessment (LCA). LCA is a scientific approach to evaluating the environmental impact of a product throughout its life cycle. LCA is frequently referred to as a "cradle-to-grave" approach, although with the addition of comprehensive recycling programs, it may also be called a "cradle-to-cradle" approach that tracks the impact of a product from the initial extraction of raw materials to the

final recycling of these materials into new products.

The product life cycle

The term "life cycle" refers to the major activities in the course of the service life of a product, from its manufacture, use, and maintenance, and up to its final disposal. Figure 1 illustrates the life-cycle stages in a typical LCA, along with the inputs and outputs to be considered:

Environmental Impacts

Environmental impacts are the result of the inputs and out-

puts over a product's life cycle. Inputs such as raw materials and energy carry with them environmental impacts just as much as obvious environmental outputs such as atmospheric emissions and solid wastes. Although the total number of different potential environmental impacts may be very large, the U.S. Environmental Protection Agency has identified the "top ten" impact categories

in its widely-used TRACI (Tool for the Reduction and Assessment of Chemical and other environmental Impacts) tool. These ten impact categories, along with the measures employed, are listed in Table 1.

In addition to identifying the major threats that impact the long-term viability of the environment and human health, the TRACI methodology also identifies specific measures to apply to each impact. As an example, although many hazardous chemicals may contribute to cancer, the TRACI scale measures all of these

TRACI Impact Category:	Impact Measure:
Global Warming Potential (GWP)	kg CO ² Equivalent
Ozone Depletion Potential (ODP)	kg CFC Equivalent
Photochemical Oxidant Potential (PCOP)	kg NOX Equivalent
Acidification Potential	H ⁺ Moles Equivalent
Eutrophication	kg Nitrogen Equivalent
Health Toxicity (Cancer)	kg Benzene Equivalent
Health Toxicity (Non-Cancer)	kg Toluene Equivalent
Health Toxicity (Air Pollutants)	kg: DALYs Equivalent
Eco-Toxicity Potential	kg 2,4-D Equivalent
Fossil Fuel Use	mJ Surplus Energy/ mj Extracted Energy

Source: Bare, Norris, Pennington, & McKone, 2003, p.55.

Table 1 - TRACI impact categories and measures.

threats in terms of their equivalency to Benzene, a well-documented carcinogen. In a similar manner, the potential for depletion of the earth's ozone layer is measured in terms of equivalency to the impact of CFC-11, or the once-popular "Freon" that has been linked to the depletion of the ozone layer.

The LCA Process

Once relevant inputs and outputs have been identified and a measurable scale has been developed for each impact, LCA provides a methodology to apply this information to decision-making. According to the U.S. Environmental Protection Agency (EPA, 2007), an effective LCA process may be divided into three basic steps:

1. Compiling an inventory of relevant energy and material inputs and environmental releases.
2. Evaluating the potential environmental impacts associated with identified inputs and releases.
3. Interpreting the results to help in making an informed decision.

Because the LCA process involves a final step of interpreting the results, LCA is employed frequently as a comparative method to make decisions among alternatives. For example, one of the first applications of LCA involved the packaging of soft drinks, conducted by Coca-Cola Company in the 1970s (Duda & Shaw, 1997). At the time, Coke was considering replacing its returnable glass bottles with disposable cans or plastic bottles. Because of emerging public concern regarding the potential environmental damage of disposable containers, the company wanted to fully explore comparative environmental impacts before making a decision. To the surprise of

many at the time, the LCA conducted by Coke demonstrated that plastic bottles were the best environmental choice, because each plastic bottle consumed and emitted fewer hydrocarbons than the alternatives.

LCA and Durability

Because the primary measures used in LCA involve many indirect environmental costs of a product, LCA differs from traditional Life Cycle Cost analysis (LCC), which focuses primarily on the direct economic impact of a product. As a result, LCC may be more directly related to a product's durability as reflected in its service life. However, if environmental impact is considered to be the best measure of economic cost in the long run, then LCA may be considered in some ways to be a more accurate form of traditional Life Cycle Cost. And if the long-run environmental impacts of a product are indeed the best reflection of its true economic cost, then LCA should be equally as sensitive to the comparative durability of materials as traditional LCC. For example, if an apparently "environmentally friendly" roofing system with a useful service life of under 20 years is compared to a slightly less "friendly" roofing system with a service life of over 30 years, the environmental impact of the apparently superior roof will be increased by the relative difference in service life between the two alternatives. As a result, the increased environmental impact of a lower service life may make the apparently environmentally friendly roof an inferior choice.

Benefits of LCA

By focusing on the totality of environmental impacts, LCA may help avoid shifting impacts from one place to another. As an example from the Coca-Cola LCA discussed previously, the continued use of glass bottles in lieu of plas-

tic bottles would not have reduced overall environmental impact. Rather, it would have shifted the environmental burden to the energy required and the wastewater generated to collect, clean, and re-use glass bottles. In this example, LCA also was useful in identifying the lowest impact choice (plastic bottles) among a number of alternatives (glass bottles and aluminum cans). LCA also allows analysis of trade-offs to promote informed decisions. As an example, the use of glass bottles in a less-developed area of the world may be the best choice when imports of plastics may be relatively expensive and recycling efforts involve fewer mechanized (and energy-intensive) processes.

The benefits of LCA are beginning to affect the construction industry the same way it previously influenced the selection of containers for soda. Prior to conducting a comprehensive LCA of different alternatives to mixing concrete, it was assumed by many engineers and designers that concrete with a high level of limestone aggregate was more environmentally beneficial than concrete with a high level of fly ash. Although limestone itself is less environmentally hazardous than fly ash, limestone concrete requires higher levels of Portland cement to achieve the same compressive strength, and this increase in the amount of Portland cement makes the overall environmental impact of limestone concrete higher than fly ash concrete (Lippiatt & Ahmad, 2004). Certainly, in the case of the concrete industry, the use of LCA will enable the best environmental decisions to be made, even when these decisions may appear to contradict current consensus regarding environmental "friendliness."

Limitations of LCA

Although the LCA method may reduce total resource use, the method itself is resource- and

time-intensive. Calculating the environmental impact of single products using TRACI or a similar methodology may require hundreds of hours of research and thousands of dollars of investment. For a simple roofing system composed of a membrane, adhesives or fasteners, insulation, flashings and accessories, the total cost for even a basic LCA may exceed \$100,000. However, investment in LCA may be viewed as accumulative, similar to investments in fire- and wind-rating testing. Each fire and wind-uplift test provides information that adds to the overall body of knowledge and reduces the need for additional testing. But an industry-wide LCA product initiative will likely have a high start-up cost to get the first basic products tested and reviewed.

Although LCA may be very useful in determining the overall environmental impact of a construction product or system, LCA cannot determine which product is the most cost-effective or which will work the best. As an example, LCA may indicate that foam insulation without a cover board provides the lowest environmental impact for a roof insulation system. However, life cycle assessment itself may not give sufficient weight to the need for durability and resistance to roof traffic that a cover board provides. As a result, LCA still requires that a value judgment be made about the suitability of the product analyzed and the validity of the LCA measure.

Current Status of LCA

Regardless of the benefits and limitations of LCA, life cycle assessment is here to stay. Although a detailed history of LCA is beyond the scope of this paper, the importance of LCA may be validated by its incorporation in the ISO 14000 series of standards. Like the ISO 9000 series that has

influenced corporate quality management systems across the globe, the ISO 14000 series of standards is rapidly influencing how corporations manage and measure environmental responsibility. Although many parts of ISO 14000 involve how manufacturing facilities are managed, a significant portion of the ISO 14000 standards involves how manufactured products are managed. The first portion of the ISO 14000 series affecting products is ISO 14040, which outlines how LCA should be applied as a product evaluation tool. And building on LCA analysis, an additional standard - ISO 14020 - outlines how the environmental impacts of all products should be documented and communicated to the marketplace. Specifically, ISO 14020 calls for the implementation of a standardized format for communicating product environmental impact, called an Environmental Product Declaration (EPD). Like most ISO approaches to standardization, EPDs require the development of ongoing documentation of environmental impact as well as third-party certification of the impact data.

The Future of LCA

With a recognized and powerful international standard such as ISO 14000 in place, it is likely only a matter of time until every product used in the construction industry will carry with it a documented EPD or similar environmental certification. In fact, this process is well underway in Europe, where products with formal EPDs now include almost every major construction material. In the United States, a small number of companies have begun to publish similar declarations for building materials, including metal roofing, concrete additives, exterior coatings, and paving materials.

In addition to increasing the publication of LCA-based disclosures for building products, ISO 14020 and 14040 will drive standardization in the methods and standards used to rate and classify materials. In turn, this will lead to the establishment of environmental benchmarks for building materials that will begin to appear in building design specifications and certification programs such as LEED. In the not-so-distant future, all building envelope professionals, including manufacturers, consultants, and contractors, will be dealing with LCA-based product standards on a daily basis.

LIFE CYCLE ASSESSMENT AND LEED: THE USGBC RESPONSE

In response to concerns about material durability, the USGBC has initiated a significant program to incorporate Life Cycle Assessment (LCA) into the structure of LEED, so that the long-term performance of building components is given greater consideration. On January 25, 2007, USGBC's Life Cycle Assessment Working Group formally published its first set of recommendations for incorporating LCA as part of the LEED Green Building Rating System. The recommendations included short- and long-term implementation strategies as well as technical details regarding LCA methodology. "Until now, there hasn't been much work done incorporating LCA into U.S. building practice because of limited research," said Tom Hicks, vice president of the U.S. Green Building Council. "We are venturing into new territory, but as the nation's leading green building organization, USGBC has a responsibility to ensure that LEED's evolution addresses LCA in a meaningful and relevant manner." (USGBC press release, January 26, 2007.) According to the USGBC, the LEED Steering Committee has begun considering the recommen-

dations of the LCA Working Groups and had expected to complete an LCA plan very shortly if it is not completed by the time this paper is published.

HOW WILL LCA IMPACT LEED?

In the long term, LCA will be applied to integrated building systems by combining the EPDs of each product incorporated in a project into a single overall environmental impact assessment. According to the USGBC, its "long-term objective is to make LCA a credible component of integrated design, thereby ensuring that the environmental performance of the whole building takes into account the complete building life cycle." (USGBC press release, January 26, 2007.) However, the USGBC also recognizes it will take time for LCA to be so fully integrated into the building design process.

In an effort to move toward this goal as quickly as possible, however, the USGBC has selected building structure and building envelope as the two primary starting points for LCA. This means that the task groups working on LCA will focus primarily on standards relating to major structural and envelope materials, including roofing systems, wall systems, water and air barriers, and thermal insulation. USGBC envisions that these structural and envelope systems will be ranked according to their environmental impact, with LEED credits awarded accordingly.

Although a formal LCA program tied to specific LEED credits may be a few years off, the USGBC has initiated a short-term program to allow LCA to impact LEED credits immediately. In a series of press releases in 2007, USGBC has announced that projects using building materials that have been assessed and rated by specific third-party organizations may be eligible for immediate

"Innovation in Design" credits under the current LEED standard. These third-party certification programs include the Cradle-to-Cradle (C2C) benchmarking program offered by MDBC, the Sustainable Materials Rating Technology (SMART) system developed by the Institute for Market Transformation to Sustainability, and the California Gold program of the State of California (USGBC Press Releases, May 1, 2007, and July 3, 2007). Although these programs are still in their infancy, a number of pioneering manufacturers already have obtained product certifications, and it is assumed that these companies will begin actively promoting these products to the design community for inclusion in LEED projects.

HOW WILL LCA IMPACT THE BUILDING ENVELOPE INDUSTRY?

Undoubtedly, the first effect on the building envelope industry of USGBC's LCA initiative will be seen in increasing demands for EPDs or similar product declarations for almost every building material used to construct the building envelope. Although the cost of obtaining these product declarations will be expensive and time-consuming, it is difficult to envision how the industry can resist this demand. Based on the growing influence of LEED in its current form, it is likely that considerable public pressure will be placed on the industry to develop accurate environmental product data. In addition, because many major building materials manufacturers are already working hard to achieve and maintain ISO 14000 registration for their physical plants, it may be reasonable to assume these same companies will extend their environmental efforts to include ISO 14020 and Environmental Product Declarations.

Over the next few years, an accelerated effort on the part of materials manufacturers to produce product declarations and certifications will also undoubtedly generate considerable confusion in the marketplace. To help "get the ball rolling," the USGBC has opened the door for confusion by approving the three separate rating systems previously mentioned to vie for attention of the building designer. And these rating systems are sure to cause confusion and contradiction simply based on the diversity of their current formats.

In addition, all of these systems appear to go well beyond the material impact of products by requiring eligible companies to profess "fair labor" practices and conduct third-party assessments of "social responsibility" in addition to complying with environmental standards. Although it is not the intent of this paper to judge the validity of these more socially-oriented standards, it is likely these concepts are yet little-recognized by the general public; and they may inject an unexpected political overtone to the entire agenda of sustainable construction.

Eventually, however, the clouds of confusion surrounding LCA will dissipate as standards become more uniform and the practice of life-cycle assessment becomes more common. When LCA is effectively integrated into the LEED program, the building industry will certainly face a new playing field; but the playing field may be much improved. In the place of anecdotal claims regarding the "green" benefits of products, the building envelope industry will be able to provide logical and comprehensive information about its products that will allow building designers and owners to make informed decisions. And the products themselves will likely be better designed and better ser-

viced, both initially and well after the sale. In the long run, our industry will be able to provide better value to our customers today as well as generations of customers to come.

Finally, LCA may bring some surprises to the building envelope industry. As shown in several previous examples, the actual results of a formal LCA may turn preconceived ideas about environmental benefit around. Looking at some of the first detailed product declarations from Europe, the surprises may already be evident. In a recent LCA study of building insulation, EPS and XPS exhibited a lower environmental impact than either cork or mineral fiber. The key in this LCA study appears to be a weight or mass advantage of plastics compared to natural materials. The "carbon footprint" of all organic products (whether extracted from oil or obtained from plants) tends to be directly related to the mass of the product required to perform a specific function. In the case of the current study, although the environmental impact of a kilogram of polystyrene may be greater than the impact of a kilogram of cork, the kilogram of polystyrene when expanded covers such a greater surface area and provides such a higher overall thermal value that the "natural" product has the higher environmental impact.

RECOMMENDATIONS

Increase Industry Education and Research

As a long-time observer of the building envelope industry, I must confess that my research on this paper left me embarrassed about how little we may know as an industry regarding the green building movement and its implications for our future. The idea that we may be only a few years away from an environmental product certification program as large or even larger than current

building code approval programs is, frankly, mind-boggling. As an industry, we need to learn much more about green building - and we need to learn it fast.

The risks we face as an industry are significant. Without better knowledge of the green building movement, how can we plan for the future? Which products justify new capital investment? What new business models will emerge? Without this knowledge, we may not only be in jeopardy of making bad decisions. Worse yet, decisions may be forced upon us, and by people who do not understand the importance of durability and long-term performance in the selection of building envelope materials. As I stated in a previous paper on LEED at the RCI convention two years ago:

"As an industry, we have spent far too much time and far too many dollars fixing past problems related to durability not to become unflinching advocates for the utmost importance of durability in any green-building initiative. Simply put, no building product should be considered truly sustainable unless it also meets or exceeds the desired durability of the building itself... Given the lessons our industry has learned (many the hard way), ... we should do everything we can to transfer our experience to the larger construction community." (Hoff, 2004)

Consider an Industry-Wide Initiative for Product Declarations

As mentioned previously, the looming cost for environmental product declarations may be significant, undoubtedly running into the millions of dollars. Some pioneering companies have

already embarked on this process, but organizational inertia and budget constraints may make full implementation a long and drawn-out affair. But the longer this process takes, the more confusion we will face as an industry. As a consequence, waiting for each building materials manufacturer to complete its product certifications may be neither the most efficient nor the most economical way to proceed.

At the level of analysis required by most current assessment programs, the basic chemical composition of many building products may be similar regardless of the specific brand. As an example, in the roofing industry, it is unlikely that a specific EPDM, TPO, or modified bitumen membrane will vary considerably from one manufacturer to another, especially in terms of the basic chemical analysis required by many of the environmental impact categories. As a result, manufacturers could save time and money and the industry could avoid unnecessary confusion if key industry segments worked together to develop the foundational research needed for individual product assessments. If key segments of the building envelope industry, such as roofing and waterproofing, were to develop an industry-wide approach, every industry stakeholder would benefit. Materials manufacturers could minimize the resources required for certification, designers and consultants could apply the basic research data to design roofing or waterproofing systems customized for their clients' needs, and contractors would be able to propose viable construction alternatives whenever the inevitable request for "value engineering" is received.

Combined with an intensified green building education effort, the rapid development and deployment of product declarations

by the building envelope industry would also increase the visibility of the industry and the role it plays in the development of building standards. With a serious effort to be the first construction sector to fully address life-cycle assessment, the building-envelope industry would enjoy greater recognition and influence regarding how we construct the buildings of tomorrow.

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