ENVIRONMENTAL PRODUCT DECLARATIONS:

A Primer for the Building Envelope Practitioner

By Dr. James L. Hoff, DBA

THE EMERGENCE OF DISCLOSURE IN GREEN BUILDING DESIGN

With the release of the latest version (v4) of the LEED® Green Building Rating System, the concept of disclosure has taken center stage as the next big topic in the ongoing discussion of how green buildings are defined and evaluated. And sharing the stage with disclosure are new tools that have emerged to help measure the "greenness" of building products. Many different stakeholders within the building community have been active in the promotion of disclosure, but they all tend to share the same questions. A particular building material may help save operating energy, but how does it impact other equally important environmental concerns? A product may have a high recycled content, but after the effort required to salvage, transport, and convert the material, is there still a tangible net environmental benefit? Beyond specific environmental concerns, how does the product affect the safety, health, and well-being of building occupants? Unfortunately, many of these questions cannot be answered effectively using current tools such as energy calculators and one-dimensional green product certifications.

Each of these questions is related to common concerns held not only by green building advocates but also the entire building design community: Do we have the kind and quality of information about building products to make informed decisions? Do simplistic claims or categories of "greenness" help or hinder our analysis? Do current manufacturer data sheets and reports provide adequate information? Finally, do we understand exactly what goes into the building materials we use and how these ingredients may affect the well-being of building occupants?

THE ENVIRONMENTAL PRODUCT DECLARATION (EPD)

One of the newest tools to be integrated into the selection of sustainable building materials is the Environmental Product Declaration or EPD. And while almost everyone associated with the building envelope industry has become aware of this new tool, few industry stakeholders have had the opportunity to learn about the specifics of how EPDs are developed and how they may be used. What exactly is an EPD? Why are EPDs important? Who is promoting the use of EPDs? Where will the use of EPDs and other product declarations go in the future? And most importantly, how will EPDs affect the practice of building envelope professionals?

EPDs have been around the longest of all the new product disclosure tools, and the current procedures to develop EPDs have been in place for over a decade. However, the fact that even the best-established disclosure tool is still relatively new attests to how quickly the concept of disclosure has entered the construction market. At the same time, the current EPD process has been built on a solid, science-based approach that examines total environmental impact over the entire life cycle of a product. There are many excellent definitions of EPDs, but for the purposes of this article, the EPD may best be described as a standardized process to disclose environmental impacts and other factors using quantifiable measures over the life cycle of a product as applied to a common functional unit for similar products. This definition should be especially useful when broken down into its key elements.

Standardized Process. As the environmental assessment of products has evolved, international standards have been developed to help assure that anywhere in the world, these practices are conducted in a consistent and reliable manner. In almost all cases, these procedures are based on standards adopted and maintained by the International Standards Organization (ISO). ISO standards related to the underlying practice of life cycle assessment (LCA) are contained in ISO 14040 and ISO 14045, which cover the key principles and framework of LCA as well as more detailed requirements and guidelines for completing the LCA process. ISO standards related to the specific structure of EPDs are contained in ISO 14025, which covers the basic principles for applying EPDs to all kinds of products. In addition, ISO 21930 contains additional principles for applying EPDs to building products.

The use of well-established procedures helps ensure that the information disclosed in an EPD has been developed in an objective and scientific manner. In fact, the type of EPD required by LEED® and other green

Impact Category/Environmental Indicator	Description of Effect
Global Warming Potential (GWP)*	Impact of greenhouse gasses that increase global temperatures
Ozone Depletion Potential (ODP)*	Impact of chemicals that adversely affect the earth's upper ozone layer
Eutrophication Potential*	Impact of chemicals that pollute rivers and lakes by removing oxygen
Smog Creation Potential*	Impact of chemicals that contribute to ground-level ozone and smog
Acidification Potential*	Impact of chemicals that produce acid rain
Primary Energy Consumption	Demand on energy resources and infrastructure
Resource Depletion	Demand on raw material resources
Water Consumption	Demand on water resources
Waste Generation	Demand on waste disposal facilities

*From U.S. EPA Tool for the Reduction and Assessment of Chemical and other Environmental Impacts (TRACI)

Table 1 – Typical EPD impact categories.

building guidelines must be based on ISO standards and requires a final third-party review to validate the disclosure for accuracy and reliability.

Environmental Impacts and Other Factors. In North America, the environmental impacts reported by EPDs are based on a listing of impact categories established by the U.S. Environmental Protection Agency (EPA). This listing, called the Tool for the Reduction and Assessment of Chemical and other Environmental Impacts (TRACI), categorizes a number of key environmental impacts related to the release of various chemicals into the atmosphere, ground, and water. Currently, five of the impacts are included in the data provided by most EPDs. In addition to these primary environmental impact categories, EPDs also include an analysis of the energy consumed during the product's life cycle and classify this energy into renewable and nonrenewable sources. In addition, EPDs include data regarding energy, water, and other resource consumption as well as information about hazardous and nonhazardous waste generated over the product life cycle. *Table 1* provides a listing of the typical impact categories and other environmental indicators found in EPDs, along with a brief description of their effects.

Quantifiable Measures. All of the data reported in an EPD are also quantified based on the best current science in order to allow for comparison of environmental impacts among similar products. In the case of the five key TRACI impact categories, these measures are based on chemical or molecular values that can be added to the impacts of other products to help establish an overall environmental "footprint" for a combination of products, such as a building or major building component. In the case of the other environmental indicators, the metrics are based on common measures for energy, volume, or mass. *Table 2* provides a listing of the specific metrics associated with each typical impact category and environmental indicator.

In the case of the TRACI impacts, the specific chemical selected is used as a common denominator for similar chemicals that produce a similar result. As an example, although carbon dioxide (CO_2) is the most-recognized greenhouse gas, the TRACI tool allows for the conversion of other greenhouse gasses such as methane (CH_4) and ozone (O_3) into the equivalent amount of CO_2 that would cause the same effect. Because the TRACI measures accommodate the range of chemicals associated with environmental impact, these measures can be added to the impacts of other products to establish an overall environmental "footprint" for a whole building constructed from these products. This additive nature of EPD data is very important in the development of calculators such as the Athena Impact Estimator, used to assess the environmental impacts of whole buildings or major subsystems.

Although the measures used in EPDs are quantifiable, it is important to recognize that EPDs only provide an estimate or prediction of the magnitude of these impacts. Because life cycle assessment is a modeling tool, it cannot provide an exact value of any impact. However, when conducted in accordance with recognized procedures, it can provide reasonable and comparable values that are useful for evaluating the overall sustainability of products.

The Product Life Cycle. The assessment and measurement of the environmental impacts reported in an EPD are struc-

Impact Category/Environmental Indicator	Measure
Global Warming Potential (GWP)*	Kilograms (kg) of carbon dioxide (CO_2) or equivalent
Ozone Depletion Potential (ODP)*	Kilograms (kg) of Freon (R11) or equivalent
Eutrophication Potential*	Kilograms (kg) of nitrogen (N) or equivalent
Smog Creation Potential*	Kilograms (kg) of ozone (O_3) or equivalent
Acidification Potential*	Moles of positive ions (H^+) or equivalent
Primary Energy Consumption	Megajoules (MJ) of energy consumed
Resource Depletion	Equivalent megajoules (MJ) of resources consumed
Water Consumption	Liters (l) or kilograms (kg) of water consumed
Waste Generation	Kilograms (kg) of solid waste produced

*From U.S. EPA Tool for the Reduction and Assessment of Chemical and other Environmental Impacts (TRACI)

Table 2 – Typical EPD impact measures.

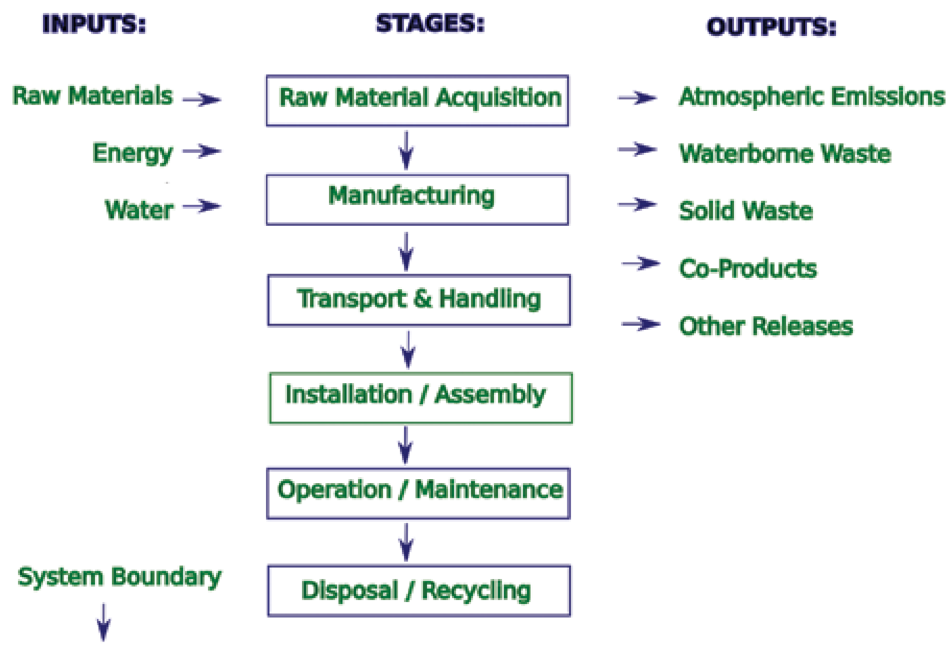


Figure 1 – Product life cycle diagram.

tured to include all aspects of a product's life cycle, from the initial acquisition of raw materials to the eventual removal and disposal of the product. This life cycle typically is described in an EPD using a diagram similar to *Figure 1*.

The concept of the product life cycle has been refined and expanded to include a number of important elements. First we start with inputs such as raw materials and energy. Next, we move these inputs through a series of processes from initial material acquisition all the way to eventual disposal and recycling. And as we move through these processes, we produce many different outputs in the form of emissions and wastes that impact the environment. One other important element in this life cycle chart is the system boundary. Essentially, it's a way to admit that we may not always capture every impact on the environment; but we need to clearly state where our assessment begins and ends. In addition, the system boundary is critical to ensure consistency and comparability among products.

To gain a clear understanding of the concept of environmental impact over the product life cycle, it may be helpful to view the EPD as an estimated measure of net product impacts over time.

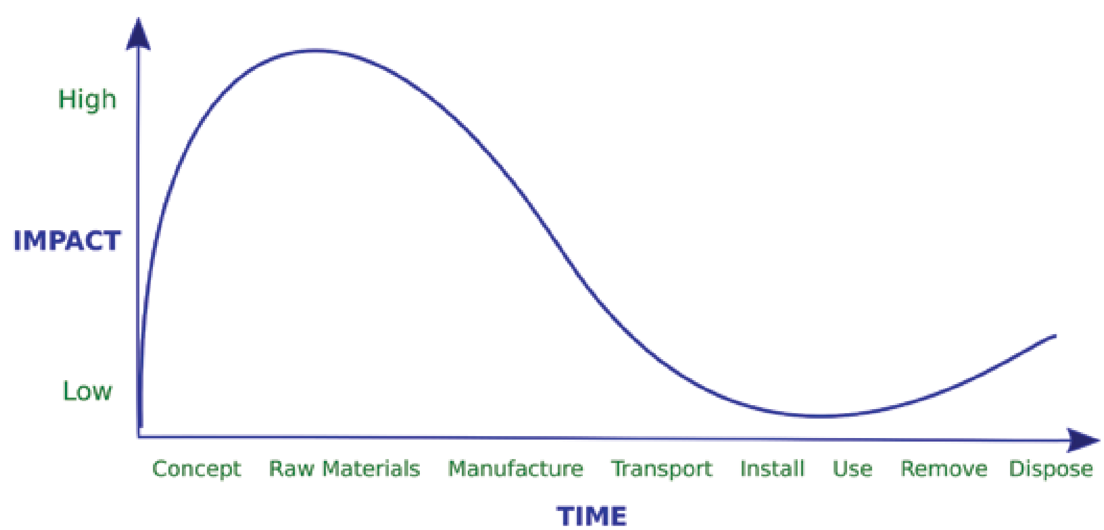


Figure 2 – The product life cycle: impact over time.

Every product starts with a design concept, which may have little or no impact. But as we acquire the raw materials, manufacture and ship the product, install and maintain it, and eventually remove and dispose of it, we add many different environmental impacts to the air, water, and land around us. And service life is a vital factor as well. The longer we can extend the useful service life of the product, the more we reduce its overall impact. An illustration of the concept of environmental impact over time is shown in *Figure 2*.

Common Functional Unit. Because the standardized ISO foundation is so critical to EPDs, it is important to note that the purpose or function of an EPD according to ISO 14025 is to enable comparison between similar products. This means that the impact data of a particular product should be comparable to impact data for a similar product with the same function. In order to accomplish this, a functional unit most relevant to the impacts associated with a group of similar products must be identified. Frequently, the basic functional unit identified within the ISO process is a measure of mass or area, such as pounds or square feet (or kilograms and square meters). Finally, the functional unit will involve a time frame as well, typically related to the service life of the product.

But how exactly do we get quantified information that can enable comparison among similar products? Again, ISO comes to the rescue with yet another acronym: the product category rule, or PCR. A PCR is intended to assure that products with similar functions may be assessed in the same way using comparable measures. PCRs are developed in accordance with ISO standards, which call for the formation of a consensus body backed by third-party validation to develop each PCR. To answer the critical issues of product comparison, the PCR establishes several key elements of how every LCA for a particular class of product should be conducted, including:

1. The functional unit and the time frame for the product
2. The system boundary
3. The impact categories to be assessed

By doing this, the PCR helps to ensure that meaningful comparisons may be made among similar products.

An example of a PCR relevant to the

Product(s) Covered	Issued To	Program Operator	Date Issued
Light and heavy-duty mineral wool board	North American Insulation Manufacturers Association (NAIMA)	UL Environment (www.ulenvironment.com)	November 8, 2013
Spray polyurethane foam for insulation and roofing systems	Spray Polyurethane Foam Alliance (SPFA)	UL Environment (www.ulenvironment.com)	October 10, 2013
Polyiso roof insulation	Polyisocyanurate Insulation Manufacturers Association (PIMA)	NSF (www.nsf.org)	January 1, 2015
Polyiso wall insulation	Polyisocyanurate Insulation Manufacturers Association (PIMA)	NSF (www.nsf.org)	January 1, 2015

Table 3 – Published generic EPDs for building thermal insulation.

building envelope practitioner was developed recently by a broad coalition of insulation manufacturers under the third-party stewardship of Underwriters Laboratories (UL).[1] This PCR covers all building envelope thermal insulation, including fiberglass, mineral wool, expanded polystyrene, extruded polystyrene, polyiso, and many others.

This thermal insulation PCR uniquely defines the functional unit as a square meter of insulation with a metric or "RSI" value of 1. That's very important because the thickness required to obtain an RSI value of 1 varies significantly among different insulations. And in many cases, we really don't care exactly how thick the insulation is, because the critical function of insulation is related to the ability to resist heat transfer as measured in R-value. The PCR also identifies the service life to be 60 years, which is currently the standard for typical building service life in the new International Green Construction Code (IgCC). And unless damaged by unforeseen forces, most thermal insulations have a service life of 60 years or more when protected within a wall, ceiling, or roof assembly. Finally, the thermal insulation PCR establishes the system boundary to be cradle-to-grave, which includes all processes leading up to the delivery of the insulation to the job site; its installation during construction; its maintenance over the service life; and its removal, disposal, and possible recycling at the end of its service life.

EPDs AND THE BUILDING ENVELOPE

Because of the structure provided by underlying ISO standards and a relevant PCR, most EPDs follow a similar format. In general, the basic requirements for a typical EPD for a building material can be met in a relatively short document—perhaps three to four pages. However, because current standards provide a number of options in regard to supplemental information that may be provided in an EPD, some EPDs can be much longer and contain a wide variety of graphics and pictures.

As previously mentioned in the discussion of the newest LEED® credit for product disclosure, EPDs may be either generic or proprietary in scope. Generic EPDs disclose data relating to a common product produced by multiple manufacturers, and the impacts disclosed are based on a weighted average of their combined production. Proprietary EPDs disclose data relating to a single product produced by a single manufacturer, and the impacts disclosed are based on the total production of that manufacturer.

Because of the expense associated with the development of EPDs, many of the early EPDs now available are generic rather than proprietary. By joining together to develop a common EPD for functionally similar products, individual manufacturers can pool their resources and achieve economies of scale. In addition, end users are provided with a useful "baseline" for functionally similar products that may be useful in developing nonproprietary specifications. Within the building product arena, generic EPDs have been among the first EPDs to be published. As an example, within the last two years, four detailed generic EPDs have been published for building thermal insulation products. *Table 3* identifies the products covered by these EPDs as well as the organization initiating the EPD, the program operator publishing the EPD, and the date of issue.

Copies of these EPDs are maintained by the program operator and are available for download at no charge from the websites referenced in *Table 3*. In addition to the generic EPDs listed in this table, a number of individual manufacturers have published proprietary EPDs for a variety of thermal insulation products, including glass fiber batt and extruded polystyrene (XPS) boards. In all cases, these EPDs are based on the same PCR, and all have been certified as ISO 14025-compliant.

In addition to following the same PCR, the overall format of these EPDs is very similar. Each EPD starts with a certification page verifying the EPD was developed in accordance with ISO 14025 standards, including third-party verification by the program operator. In addition, the certification page identifies the PCR used to develop the EPD and the organization that performed the basis LCA for the EPD.

Inside each EPD is a life cycle diagram showing all the processes, inputs, and out-

Polyiso Roof Insulation Impact Assessment (LCIA) Results For 1 m^2 of Polyiso roof insulation with RSI = $1 m^2 \cdot K/W$	
Impact Category / Environmental Indicator	**Measure**
Global Warming Potential (kg CO_2 equiv.)	2.80
Acidification Potential (mole H^+ equiv.)	9.08E-02
Eutrophication Potential (kg N equiv.)	1.40E-03
Smog Creation Potential (kg O_3 equiv.)	0.180
Ozone Depletion Potential (kg R-11 equiv.)	9.40E-08
Primary Energy Demand (MJ)	53.10
Resource Depletion (kg)	5.10
Waste to Disposal (kg)	0.914
Water use (l)	170.00
Waste to Energy (kg)	3.00E-04

Table 4 – Typical summary impact table for a thermal insulation EPD. Source: PIMA.[4]

puts included within the required system boundary. In addition, the EPD will contain additional charts and figures to help explain the makeup and function of the product, including product illustrations, manufacturing process flows, and typical construction details. EPDs also may include a broad range of additional information that may be helpful to the end user. These may include:

- References to relevant product technical standards
- Key performance information, such as fire resistance and moisture resistance
- Other environmental benefits, such as energy payback, recycled content, etc.
- Information regarding the use of the product toward achieving LEED® credits

Each thermal insulation EPD also specifically identifies the functional unit used to measure all environmental impacts. As previously discussed, the functional unit for thermal insulation is a square meter of insulation with a metric or RSI value of 1. Frequently, the EPD will provide additional information to help the end-user better understand the functional unit. As an example, a thermal insulation EPD may discuss exactly how R-value is measured for the product, as well as how to convert RSI values into "inch-pound" R-values (RIP).

Finally, each EPD will contain a summary table of impacts, which is undoubtedly the most important part of the disclosure document. *Table 4* provides an example of a summary impact table taken from the EPD for generic polyiso roof insulation previously referenced in *Table 3*.

A number of important elements may be identified in this typical impact table. First, the table identifies the specific impact categories/environmental indicators for which impacts are reported. As an example, the first impact category shown in the table is Global Warming Potential. Next, the table identifies the impact units for each impact category. In this case, the impact unit for Global Warming Potential is kilograms of CO_2, or carbon dioxide equivalents. In addition, the table identifies the specific impact measure, which is 2.32 kilograms of CO_2 equivalents. Finally, the table identifies the functional unit used to determine each impact measure, which is a square meter of insulation with an RSI value of 1.

This typical impact table also illustrates a very important feature of many EPDs that may be problematic for the less mathematically inclined reader. Because many of the unit impacts identified in the EPD are relatively small for the given functional unit, scientific notation is frequently used to express the measurement. As an example, "eutrophication potential" in the summary table shown in *Table 4* is stated as 1.28E-03 in scientific notation. In decimals, this would be 0.00128, or 1.28 thousandths.

HOW WILL EPDS BE USED?

Life Cycle Databases. One of the most important uses of the data disclosed by EPDs will be the continuous improvement of our databases of life cycle information. This will be a very important function of EPDs, since databases of reliable and relevant life cycle information are critical to the development of accurate and useful EPDs. In some ways, this can be viewed as a virtuous cycle where each new EPD helps to improve our underlying life cycle data, which in turn improves the accuracy of the next EPD.

Whole-Building Life Cycle Assessment. A second and very important use of the data from EPDs is to help to build useful tools to evaluate complicated assemblies of products, which is especially important in the development of relevant whole-building life cycle assessment. Some of the best-known whole-building assessment tools that rely on these databases include the Athena Impact Estimator, developed by the Athena Institute in Canada; and the Building for Environmental and Economic Sustainability (BEES) software program, developed by the National Institute of Science and Technology (NIST).

Continuous Manufacturer Improvement. The ISO 14000 series of standards for LCA and EPDs are very similar to the better-known ISO 9000 series of standards for quality management. Both of these standards emphasize the importance of continuous improvement in the achievement of higher product quality (in the case of ISO 9000) and product sustainability (in the case of ISO 14000). As part of larger sustainability initiatives, many prominent manufacturers already have adopted ISO 14000 practices to measure and improve their environmental "footprint," and the use of EPDs will help form a baseline for new levels of product sustainability and reduced environmental impact.

Green Guidelines and Codes. EPDs and the information they provide will be incorporated into a number of emerging green building guidelines and codes—first as a prerequisite for the selection of preferred products, and later as a means of additional evaluation based on the actual impacts disclosed. Over the next few years, you'll be hearing more and more about LCA in green guidelines, codes, and standards.

Perhaps the best example of the integration of EPDs into green guidelines may be found in the LEED® green building rating and certification system developed by the U.S. Green Building Council. EPDs already are included in the current version (LEED® 2009), or at least in several optional pilot credits that may be used with the current LEED® program. LEED® Pilot Credit 43 introduces the use of EPDs as one of several ways to demonstrate that products used in the project are covered by some type of environmental product certification or verification. The emergence of EPDs will also be very helpful in supporting Pilot Credit 1, which involves the use of the Athena Impact Estimator to conduct a life cycle assessment of the whole building or one or more major building assemblies. As mentioned previously, EPDs effectively funnel new data to help expand the scope and reliability of tools like the Impact Estimator.

In the LEED® v4, these pilot credits are integrated into the main body of the guideline. The first credit (MRc1, Building Life Cycle Impact Reduction) continues to support the use of tools like the Athena Impact Estimator to evaluate the life cycle impacts of the whole building. The second credit (MRc2, Material Disclosure and Optimization) promotes the use of EPDs—both generic and proprietary. Specifically, generic EPDs developed by a coalition of manufacturers are allowed a half credit toward the calculation of at least 20 products with EPDs, while proprietary EPDs developed by a single manufacturer are allowed full credit.

LCA also is being integrated into other green product certification programs. Generally, these certifications are developed under an ANSI or similar consensus process, and they typically include a listing of desired product attributes to be evaluated as part of the certification procedure. Many of these certifications are part product standard and part rating system, assigning points for meeting certain product attributes and awarding overall levels of achievement. LCA and EPDs are frequently required as one of the many attributes evaluated by these certification programs. Two recent examples of green product certification standards include a new standard for sustainable single-ply roofing membranes developed by NSF (formerly the National Sanitation Foundation) and a proposed standard for thermal insulation currently being developed by Underwriters Laboratories (through their new subsidiary, UL Environment). Both of these standards include EPDs as one credit within a multiple-credit scoring system.

Finally, LCA is being added to building codes, most notably the IgCC, which is being adopted by local code jurisdictions as an overlay to current baseline building and energy codes. Currently, the IgCC includes whole-building LCA as a jurisdictional elective, meaning that the individual jurisdiction can elect to require whole-building LCA. However, in the 2015 version of the IgCC (to be issued this spring), products with EPDs will be included as a co-equal alternative to products with recycled content, bio-based content, or other single sustainable product attributes.

COMPARING EPDs

Given that a number of thermal insulation EPDs have now been published, is it possible to make meaningful comparisons among the data reported in these EPDs? The answer must be qualified. As stated previously, EPDs for similar products must use the same Product Category Rule so that the scope, methodology, data quality, and specific environmental indicators are equivalent. However, several other important caveats should be noted. First, LCA and the development of EPDs is a very young practice, especially in North America. Although we have well-established ISO standards, we still may experience considerable variations within the actual application of those standards. In addition, the underlying LCA databases are evolving constantly as new data becomes available. As a result, it is possible that the newest LCA data may contain different levels of impact—simply due to improvements in measurement precision.

The way similar materials are installed within a building also may affect the validity of comparisons. As an example, building insulation may be installed either continuously over the wall framing or roof deck, or it may be installed within wall or roof cavities. When it is installed continuously, the R-value provided is uniform. However, when installed within a cavity wall, the overall R-value is reduced by the lower R-value of the framing materials, such as 2x4s or concrete block. This means that the functional R-value per square meter of wall or roof area will be lower than the functional unit of the insulation EPD, and as a result, an effective comparison between an insulation product installed continuously and an insulation product installed within a cavity is not possible.

Finally, and perhaps most importantly, minor differences among small building components may not yield significant impact savings when applied to an entire building. The concept of size versus the effect of any particular impact is very important. In many cases, the measured impact may be so small that even when you scale up from the functional unit to an entire building, the overall impact remains relatively minimal.

The use of scientific notation for very small measures of impacts in EPDs may help to illustrate the issue of impact size and effect. To expand our understanding of size and effect, let's go back to the example of the impact of eutrophication in the generic polyiso roof EPD previously discussed. In the EPD impact table for polyiso roof insulation shown in *Table 4*, the eutrophication impact of one square meter of polyiso roof insulation at the prescribed functional unit is 1.40E-03 or 1.40 thousandths of a kilogram of nitrogen. If we extrapolate this measure to a 10,000-square-foot building with R-20 roof insulation, the net eutrophication potential for the roof insulation would amount to slightly more than 4 kilograms of nitrogen.

Converting this amount of nitrogen into a more tangible example, those 4 kilograms of nitrogen would be equal to the amount of nitrogen in fertilizer needed to produce approximately four bushels of corn. So, if you were able to find a roof insulation with only half the eutrophication potential as in this example, the net environmental savings over the entire lifetime of the building would be equal to the net impact of two bushels of corn. Now, that's not to say that every bushel of corn isn't important. But there are probably many other energy and environmental impacts to consider before making a definitive judgment regarding the use of a particular insulation material based on eutrophication potential alone.

For the building envelope professional, it may be important to remember that whenever comparisons are available, someone typically will use them to differentiate products in the marketplace. In some cases, comparisons may come from product manufacturers, but it is also likely that green building advocates will use comparisons to promote the use of "green" materials. As a result, it will be important for every building envelope consultant to fully understand the EPD process so that comparisons may be accurately analyzed and interpreted for clients.

SUMMARY

Based on this brief overview of EPDs, several conclusions may be suggested. First, it is likely that the EPD will become an important tool in sustainable material selection and building design. In addition, EPDs are obviously destined to play an important role in future building standards and codes. Finally, this review provides considerable support for the proposition that EPDs are being developed under rigorous standards to help assure scientific accuracy and functional comparability. However, there are a number of limitations in comparing EPDs at this time, partly due to the relative infancy of the EPD itself, as well as issues involving the significance of differences observed. As a result, the better informed a building consultant is in regard to EPD processes, the better value the consultant can provide to the end-user.

Given the number of EPDs that will become available within the next year or two, it is likely that building envelope professionals will be able to learn much more about the usefulness of EPDs in the near future. In fact, as a building researcher, I must admit I am personally interested in digging deeper into EPD data and providing additional analysis for the consulting community. Based on an initial look at many of these EPDs, I believe there will be real value—and a few surprises—as we move to a more quantifiable approach to sustainable material selection.

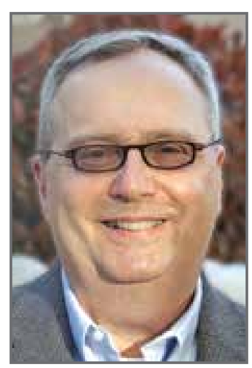
ADDITIONAL RESOURCES

For the reader looking for additional information about EPDs, the following resources may be helpful:

- EPD and LCA Practitioners
  - PE International (www.pe-international.com)
  - SCS Services (www.scsglobalservices.com)
- EPD Program Operators
  - NSF (www.nsf.org/services/by-industry/sustainability-environment)
  - UL Environment (www.industries.ul.com/environment)
- Other Resources
  - LEEDuser (www.leeduser.com/credit/NC-v4/MRc2)
  - American Center for Life Cycle Assessment (www.lcacenter.org)

REFERENCES

1. Product Category Rules for Preparing an Environmental Product Declaration (EPD) for Product Group: Building Thermal Insulation. Product Category Rule Number UL 110116, Version 1.0, September 23, 2011.
2. Environmental Product Declaration: Polyiso Roof Insulation. NSF Declaration Number EPD10043.



Dr. James L. Hoff, DBA

Jim Hoff is an experienced industry consultant, serving as president of TEGNOS Research, Inc. an organization dedicated to expanding understanding of the building envelope. Dr. Hoff holds undergraduate degrees in psychology and architectural design as well as a master's and a doctorate in management. He has published numerous articles on building system performance, quality management, and life cycle analysis. Dr. Hoff is an RCI member and serves on the RCI Foundation Board of Directors.