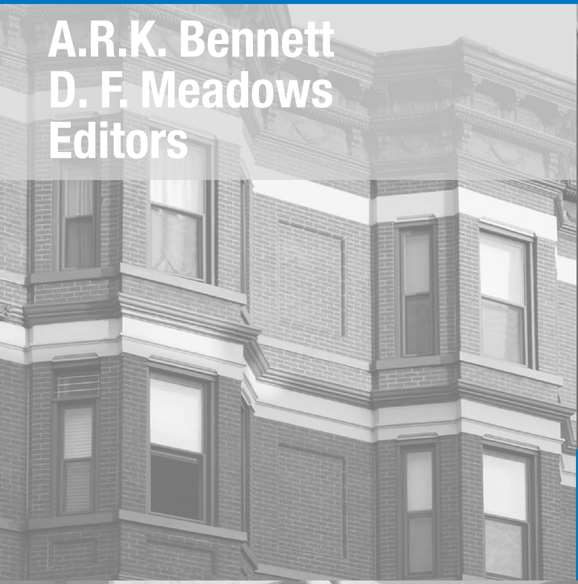
Common Ground, Consensus Building and Continual Improvement: International Standards and Sustainable Building

A.R.K. Bennett
D. F. Meadows
Editors



STP1503

ASTM INTERNATIONAL
Standards Worldwide

STP 1503

Common Ground, Consensus Building and Continual Improvement: Standards and Sustainable Building First International Symposium

Alison Kinn Bennett and Dru Meadows, editors

ASTM Stock Number: STP1503

ASTM International
100 Barr Harbor Drive
PO Box C700
West Conshohocken, PA 19428-2959

INTERNATIONAL
Standards Worldwide

Printed in the U.S.A.

Library of Congress Cataloging-in-Publication Data
ISBN: 978-0-8031-4507-8

Text printed on 30% post-consumer recycled paper.

Photocopy Rights

Peer Review Policy

Each paper published in this volume was evaluated by two peer reviewers and at least one editor. The authors addressed all of the reviewers' comments to the satisfaction of both the technical editor(s) and the ASTM International Committee on Publications.

The quality of the papers in this publication reflects not only the obvious efforts of the authors and the technical editor(s), but also the work of the peer reviewers. In keeping with long-standing publication practices, ASTM International maintains the anonymity of the peer reviewers. The ASTM International Committee on Publications acknowledges with appreciation their dedication and contribution of time and effort on behalf of ASTM International.

Citation of Papers

When citing papers from this publication, the appropriate citation includes the paper author(s), "paper title", J. ASTM Intl., volume and number, ASTM International, West Conshohocken, PA, Paper, year (listed in the footnote to the paper), Paper ID JAI100887 (located at the top of each first page). This book is a repackaging of those papers.

Printed in Mayfield, PA
February, 2009

Foreword

This publication, *Common Ground, Consensus Building, and Continual Improvement: Standards and Sustainable Building*, contains papers presented at the first international symposium of the same name held in Washington, DC, on 19-20 April, 2007. The symposium was sponsored by the ASTM International Committee E06 on Performance of Buildings, Subcommittee E06.71 on Sustainability. The symposium co-chairs were Alison Kinn Bennett, EPA and Dru Meadows, theGreenTeam, Inc.

The symposium, a first of its kind, brought together governments, professional organizations, trade organizations, industry, standard developing organizations, and environmental organizations in a discussion about current and developing sustainable building and product standards. Furthermore, the symposium highlighted opportunities and needs for coordination and consensus in the marketplace. Twenty-three papers were presented at the symposium. This book contains a selection of 13 symposium papers published by the Journal of ASTM International (JAI). JAI is an online, peer-reviewed journal for the international scientific and engineering community. Publication in JAI allows rapid dissemination of the papers as soon as they become available, while publication in this Special Technical Publication (STP) is intended to provide easy access to the condensed information in a single volume for future reference.

Contents

Overview

Environmental protection has evolved. There is a new "movement" afoot. Building on the foundation of governmental programs, both regulatory and voluntary, a new form of governance is defining the "rules of sustainability." Standards developing organizations offer a unique forum that allows different perspectives to come together and build consensus around the issues of sustainability—defining what it means to be "green" and "sustainable" for manufacturers, designers, retailers, the general public, and the government itself.[1]

The April 2007 ASTM International Symposium *Common Ground, Consensus Building, and Continual Improvement: Standards and Sustainable Building* was a first of its kind—setting out to examine the field of standards in the marketplace and discuss their origins and evolution. By engaging governments, professional organizations, trade organizations, industry, standard developing organizations, and environmental organizations, the Symposium highlighted opportunities and needs for coordination and consensus in the marketplace.

The Symposium had superb timing—serving as a prelude to the April 24, 2007 inaugural meeting of the High Performance Building Council. The Council was formed in response to Section 914 of the Energy Policy Act of 2005. Section 914 directed the U.S. Department of Energy to work with the National Institute of Building Sciences (NIBS) to assess current voluntary consensus standards and rating systems for high performance buildings and to recommend steps to fill gaps. The key objectives identified for a high performance building include: accessibility, aesthetics, cost effectiveness, functional/operational, historic preservation, productive, secure/safe, and sustainability.

The ASTM Symposium demonstrated that sustainable building standards are at the forefront of high performance building objectives in many ways: taking a holistic, systems approach to defining environmental preferability; pushing the science of life cycle assessment; asking the tough questions about chemicals of concern; balancing environmental, economic, and social considerations; and responding to consumer demand by communicating the keys to responsible purchasing. Furthermore, the leaders in sustainable building standards development are engaging stakeholders in an open, transparent process—demonstrating that consensus can bring real industry transformation.

This is evident in the success ASTM's Subcommittee E06.71 on Sustainability has had over the past 10 years in forging standards development in the areas of general principles and terminology of sustainability relative to buildings; data collection for sustainability assessment; environmentally preferable products; green power; vegetative roofing systems; and earthen materials.

As E06.71 publishes this volume, we look forward to a future Symposium on Standards and Sustainable Building to reengage in this all-important and ever-evolving discussion. We encourage all readers to participate in ASTM's work on sustainability. Your participation and feedback help to advance the industry. Together we will build a strong foundation for a sustainable future.

---

*In the US, the federal government is largely behind this shift in governance toward voluntary consensus standards and ecolabelling programs. The National Technology Transfer and Advancement Act (NTTAA) (P.L. 104-113: 1996) and the Office of Management and Budget (OMB) Circular A-119 direct federal agencies to make use of voluntary consensus standards rather than government-unique standards in procurement and regulations.

Finally, we would like to gratefully acknowledge the outstanding quality of the contributions made by the authors as well as the dedicated efforts of the peer reviewers and the staff of ASTM and AIP, who all helped to make the 2007 symposium and the publication of the associated papers possible.

Alison Kinn Bennett
Co-Chair EPA Green Building Workgroup
US Environmental Protection Agency
Office of Pollution Prevention and Toxics
Environmentally Preferable Purchasing Program

Dru Meadows, AIA, CSI
Principal, theGreenTeam, Inc.
Chair ASTM E06.71

Journal of ASTM International, Vol. 5, No. 2
Paper ID JAI101184
Available online at www.astm.org

Tom Lent[1] *and Bill Walsh*[1]

Rethinking Green Building Standards for Comprehensive Continuous Improvement

ABSTRACT: Climate change is only one of a series of challenges for which members of the scientific community are suggesting urgent action on a global scale to avoid irreversible health, environmental, and social damage. Labels and standards can play an important role in transforming our material economy to address these problems. Current trends in standard setting, however, threaten to confuse consumers and may actually stifle innovation. The problems of climate change and persistent bioaccumulative toxicants (PBTs) and the host of other resource depletion, toxicity, and social justice issues presented by current building material practice are urgent but complex. A rethinking of our approach to standards and labeling from a goal-oriented, strategic perspective can help resolve tradeoffs and energize markets to deliver better goods that strive toward sustainability ideals. Effective standards and labels must be: clear about their ultimate goals, comprehensive in scope, able to deal with uncertainty and data gaps, transparent, and designed to reward continuous improvement. The U.S. Green Building Council (USGBC) has initiated a process that demonstrates components of this strategic approach in addressing climate change. HBN's Pharos Project is seeking to provide a framework to help map out and facilitate that strategic approach by establishing ideals in each category of impact and a roadmap to score progress toward that goal. The project models the use of this approach on a building material product database with a full range of environmental attributes and tools for evaluation.

KEYWORDS: climate change, persistent bioaccumulative toxic, PBT, building materials, rating systems, third party certification, USGBC, LEED, Pharos Project, precautionary principle, environmental health, LCA

Facing Multiple Interrelated Environmental Challenges

It is now accepted that the crisis of climate change looming over society gives urgency to the challenge of transforming the way we manufacture and use energy. Climate change, however, is not the only global environmental health issue for which researchers are seeing an increasing urgency to address. Species extinctions, wetlands loss, fresh water scarcity, soil depletion, and an increasing array of human health impacts linked to chemical exposures are examples of issues that don't currently garner the headlines that climate change does, but are escalating rapidly under the radar and potentially pose threats to future human health and survival in ways that may soon appear just as dramatic as climate change now does.

Compare, for example, the well known graph illustrating the dramatically escalating concentration of CO_2 in the atmosphere that threatens radical climate change with a similar graph showing the escalating concentration of persistent bioaccumulative toxicant (PBTs) in humans (Fig. 1). The PBTs shown here are polybrominated diphenyl ethers (PBDE), a class of chemicals widely used as flame retardants in furniture and other plastic materials.

The units of measurement are different, but in both cases introduction of the chemical—into the atmosphere for CO_2 or into human milk for PBDEs—is happening faster than removal, leading to increasing concentrations.

As with CO_2 and climate change, the increases of PBT chemical concentrations in living organisms present the risk of significant harm to human health and the environment but high uncertainty about specifics of mechanisms and effects. In both cases, efforts to control or sequester problematic emissions are proving to be inadequate and ineffective to address the scope of the problem. Change of technologies and materials to avoid creating the compounds in the first place is the policy of choice—whether for climate change gases or toxic chemicals. These conditions make both issues textbook cases for application of the Precautionary Principle to decision making.

Manuscript received April 16, 2007; accepted for publication December 17, 2007; published online January 2008.
[1] Healthy Building Network, 2464 West St., Berkeley, CA 94702

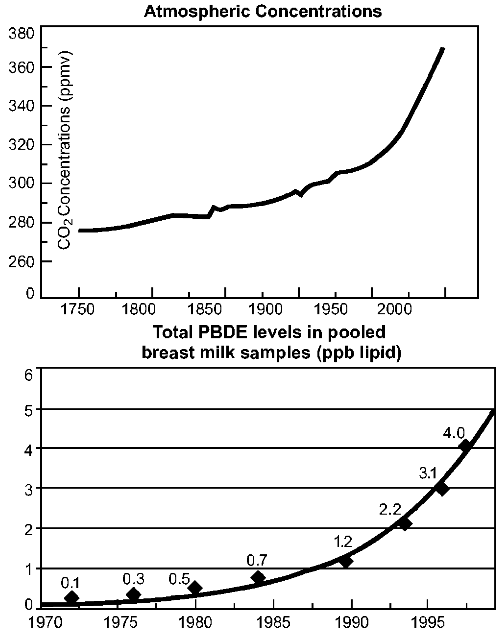


FIG. 1—*Graphs of atmospheric concentrations of carbon dioxide and of concentrations of PBDEs in human milk showing parallel exponentially increasing concentrations levels.*

Research now suggests that toxicology may challenge the complexity of climate science as a simple linear dose-response model no longer suffices. The work of Frederick vom Saal and others on bisphenol-A is turning the traditional "dose makes the poison" toxicological view on its head—revealing that endocrine disruptors and other toxic chemicals can disrupt basic functioning of our bodies at extraordinarily low levels of contaminants far below the levels indicated by traditional threshold testing [1]. Meanwhile others are discovering that exposure to different chemicals in combination has synergistic effects far larger than the sum of expected individual effects, pointing to the inadequacy of individual chemical threshold testing to protect human health [2].

Conventional wisdom in chemical risk management assumes that risk=hazard × exposure and that an "acceptable risk" can be established by controlling exposures to "acceptable" levels below established safety thresholds. These bodies of research challenge this conventional wisdom, suggesting that some classes of chemicals may not have a safe level of exposure and hence cannot be satisfactorily managed at any level of production. Whereas the climate challenge is primarily involved with bringing our production of relatively abundant naturally occurring atmospheric gases back into balance with natural cycles, most of the toxics of highest concern are alien to the natural world—new creations of humanity for which the work of vom Saal and others is showing nature has virtually zero tolerance.

In both cases, increasing numbers of the scientific community are suggesting urgent action on a global scale to avoid irreversible health, environmental, and social damage. The persistent nature of some of the compounds involved and the global impacts at stake have led to unprecedented international treaties to drive down emissions—the Kyoto protocol for climate change emissions and Stockholm Treaty for Persistent Organic Pollutants for persistent bioaccumulative toxic chemical emissions.

To make matters more complex, efforts to reduce CO_2 and PBT emissions are often interrelated and can sometimes be at odds. A product substitution that reduces or eliminates PBT emissions may increase emissions of CO_2 or vice versa. Meanwhile, other challenges raised in the harvesting and extraction of raw materials and manufacture, use and disposal of building materials such as resource depletion, habitat destruction, and social justice raise the stakes to address the environmental impact of products and also raise the complexity and potential for unintended tradeoffs. Are sustainable building standards up to the challenges of finding solutions to these global problems—and of reflecting and grappling with the tradeoffs along the way?

Setting an Agenda for Labels and Standards

In June 2006, the Healthy Building Network (HBN) published a provocative article called The Label Game which challenged the conventional wisdom that the trend toward a proliferation of green labels and certifications is a clearly positive development in the effort to protect the environment and human health [3]. The article focused primarily on concerns about the independence, inclusiveness, and transparency of organizations issuing labels, noting with alarm the trend toward "greenwash" labels developed and controlled by manufacturer trade associations. Similar concerns are embodied in the *Consumer's Union* [publisher of *Consumers Report*] *Guide to Eco-Labels* [4]. The HBN article concluded: "If current trends hold, consumers can expect to be confused by a bewildering array of industry sponsored eco-labels and certifications. This will stifle innovation and inhibit market transformation."

At a moment when designers and consumers urgently need assistance in changing consumption patterns to protect health and the environment, we can ill afford to stifle innovation and inhibit market transformation. We suggest that in order to effectively contribute to the critical market transformations, standards and labels need to identify and resolve a key set of challenges.

Effective standards and labels will be:

- clear about their ultimate goals,
- comprehensive in scope,
- able to deal with uncertainty and data gaps,
- transparent, and
- designed to reward continuous improvement.

Looking at Standards and Labels from a Strategic Perspective

Green labels now abound and the lists of products that have attained them are lengthening. Most experts in the field would agree, however, that there are few if any truly sustainable building materials on the market. Manufacturers speaking to the sustainability market talk about "The Journey" acknowledging that they have a long way to go to become truly sustainable. What is the endpoint of that journey? Where is the roadmap for it? How can a product get an eco-label if it still has a journey ahead? How do we know if we are making progress—and if it is enough? Oddly enough these are questions we rarely ask.

The environmentally preferable purchasing (EPP) movement has defined many problems to address and set standards for "preferable" products that are preferred because they are considered better than standard practice. Few standards, however actually identify the end goal—the characteristics of a truly healthy long-term sustainable product, as opposed to one that is just better than current standard practice, nor provide incentive for continuous improvement beyond this first step. Life cycle analysis (LCA) can help quantify some of the impacts about which we are concerned, but still doesn't tell us if we are making significant progress in solving the problem or not. Faced with increasing species extinctions, impending loss of property, and increasing body burdens of persistent bioaccumulative toxic chemicals in humans, the clock is ticking to not just do something, but to do enough to reverse trends quickly enough to ward off irreversible harm.

We suggest that solving the problems of climate change and PBTs and the host of other resource depletion, toxicity, and social justice issues presented by current building material practice can best be done by rethinking our approach to standards and labeling from a goal oriented, strategic perspective. This can start by beginning to build a vision of what we are trying to achieve, setting goals, and refocusing materials evaluation tools, rating systems, labels and certifications toward achieving the desired results. This process can start by asking a series of specific questions:

- What is the vision of a truly healthy, sustainable, socially just product or material?
- What activities need to be changed to realize that vision?
- What specific quantifiable goals will indicate success on the path to achieving true sustainability?
- What changes need to happen in industry and the marketplace to attain these goals?

- How can we shape the tools we have available to us—such as standards and labeling—to drive toward attainment of those goals?

Clear Goal Setting: USGBC Climate Change Case Study

The U.S. Green Building Council (USGBC) is in the process now of demonstrating a strong example of the re-evaluation and goal setting process in its efforts to address the climate change challenge [5]. In the past year, the USGBC has clarified its definition of the problem of climate change and committed to addressing it aggressively with specific goals in its LEED (Leadership and Energy and Environmental Design) program for rating the environmental impact of building designs. In doing so, they have embraced the Precautionary Principle as a guiding philosophy committing to action on an issue that poses a clear significant threat to human health despite major uncertainty about mechanisms and specifics of how the impacts will play out.

They identified that to address the threat of climate change there must be an ambitious final goal of carbon neutrality—that the increase of CO_2 and other greenhouse gas emissions must be slowed, stopped, reversed, and brought back into balance. They identified that buildings (their market) account for 38 % of annual CO_2 emissions and that improving building performance can substantially reduce CO_2 emissions while improving the bottom line through energy and other savings.

Acknowledging the urgency of climate change, USGBC CEO Rick Fedrizzi has committed the USGBC to achieving results that are "immediate and measurable." The USGBC has raised its bar—mandating that all LEED projects achieve at least two of the previously optional energy credits as prerequisites and reduce CO_2 emissions over standard practice by 50 %. Significantly, the USGBC then went beyond raising the standards bar, to also set specific forward looking goals for the program and planned action to achieve those goals. They set a goal to bring in enough buildings meeting tougher LEED standards to reach one million commercial buildings and ten million homes by 2020. They also committed to increased educational efforts, achievement of their own organizational carbon neutrality, and continuous improvement of their tool's abilities to incentivize further reductions.

Not surprisingly the USGBC's move has excited and energized public and governmental support for the green building movement. This represents the very sort of rethinking and goal setting that could also make materials evaluation and rating systems very powerful forces of change in the market place. We suggest that persistent bioaccumulative toxicants and other environmental, health, and social issues warrant similarly clear and ambitious goals.

Comprehensiveness

Many standards and labels currently only address one of the many health and environmental problems raised by building materials. This is not inherently bad. There are already a number of case studies of building materials that have been reformulated in response to the proliferation of indoor air quality standards that address emissions of volatile organic compounds (VOCs) from building materials. Reducing VOC emissions from building materials is clearly an important move to improve occupant health. Without a more comprehensive context, however, single attribute standards and labeling can also actually encourage purchase of products that are less healthy or responsible for other serious environmental consequences. The same product that receives an IAQ certification for low VOC emissions may be releasing phthalate dust not measured for that certification program into the occupants' environment triggering different health problems [6]. Or its manufacture may be responsible for releasing persistent bioaccumulative toxicants or serious quantities of climate change gases. Single attribute standards are often misunderstood by consumers and specifiers to mean a general comprehensive clean bill of health for the product. Marketing and promotional materials rarely discourage and sometimes contribute to this misunderstanding.

Efforts to address multiple attributes are growing in the standard and labels world. Recent efforts that have begun to define a broader set of attributes of concern include the California Gold Sustainable Carpet Standard, NSF 140 standard for carpet, the BIFMA/NSF furniture standard under development, MTS Smart Building Standards, McDonough Braungart Design Chemistry Cradle to Cradle Protocol, EcoLogo. These and others are beginning to expand the scope of attributes to be considered together in judging environmental health and sustainability.

A variety of life cycle analysis (LCA) tools are now promoted as being completely comprehensive and accurate representations of the entire impact of building materials LCAs do indeed provide highly detailed quantifications in reference to a broader range of attributes than most other systems of analysis, but still fall far short of adequately covering a range of issues of concern, from health issues—such as exposures in the use phase of materials and the unique problems of persistent bioaccumulative toxicants that remain in the environment and travel long distances—to land use issues and social justice concerns. Furthermore their complexity restricts their usefulness as market drivers of improvement by obscuring directional guidance. As with single attribute systems, by the time LCAs make their way into marketing and promotional materials, at best the subtleties are lost, and at worst, LCAs are selectively quoted or even designed to be self-serving.

Data Gaps and Uncertainties

LCA tools as currently designed both benefit and suffer for their reliance on quantified analyses.

Depending upon the quality of data and the state of the science, they can sometimes hide as much as they reveal about the true impact of building materials. Serious uncertainties, gaps, and biases in the data currently available can radically distort results, overemphasizing some impacts while totally hiding other critical ones, all the while giving the user the impression that the tool is highly accurate, comprehensive and unbiased. HBN's analysis of comparative LCA assessments of vinyl and linoleum flooring illustrated, for example, inherent structural constraints limiting the effectiveness of LCA tools to address a range of toxic chemicals and the related human health issues, such as cancer [7]. A fundamental challenge for LCA is to deal with issues with high data uncertainty, but high potential for damage—prime candidates for precautionary principle thinking. Without this, LCAs may actually guide the user away from a good understanding of the full environmental health impacts leading to materials decisions that do not actually reflect the user's environmental goals and not providing clear market signals on specific issues of concern.

The USGBC's Technical Scientific Advisory Committee recognized the challenges for LCA to properly account for health impacts and deal with uncertainties and brought a set of other tools to bear on the same flooring comparison with strikingly different results. Where the BEES study gave much better marks than linoleum, the USGBC study found vinyl to be substantially worse overall than all flooring alternatives studied, including linoleum [8]. As the USGBC's report has shown, more creative work will need to be done to make LCA's truly reflective of data realities and the full range of health and environmental impacts.

Transparency

Open sharing of the protocols that drive ratings is fundamental to establishing the legitimacy of a standard by making it verifiable and replicable. It also makes it more of a force for change by giving clearer signals to both industry and consumers on what attainment of the standard means. This makes clear what is needed to attain the label, providing guidance to manufacturers. It also makes it possible to determine what is *not* covered by the standard allowing a healthy debate about what additional guidance – whether directly from buyer requests or through additional standard setting – is needed to encourage continuous improvement beyond the current level of the standard.

Transparency should not stop at the protocols, but should extend to the actual product data, from embodied energy calculations to chemical content. As with content and nutrition labels for food, full disclosure labeling is critical to allowing end users to evaluate products and make determinations aligned with their project needs and values. Short of full disclosure, clear standards can help begin to define the limits of product content. But without release of the data that lead to certification, the black box "trust me" approach strains credibility—particularly when the certifying agency is a trade association whose mission is to protect the interests of the manufacturers not the end user. It is also not good science. Without data there can be no confirmation through replication of results and analysis. With the necessary advent of multi-attribute certification programs, disclosure becomes all the more important. Multi-attribute certification programs often must rely on point based systems to create ratings. Doing this in a black box leaves the end user clueless as to what attributes actually led to the certification and what tradeoffs were made.

Continuous Improvement and the Three Bid Dilemma

Sustainability standards have inherent limits in their ability to be a force encouraging continuous improvement. The ideal standard would only reward products that are truly sustainable. Lacking products that meet that ideal, however, the standard needs a way to reward the best in the market and still continue to exert upward pressure even on the market leaders to strive toward the ideal. The challenge comes in dealing with the demands of market pressures on the threshold setting process. When setting a sustainability standard, there is a strong pressure to set the bar low enough to ensure that plenty of products currently on the market meet it. This pressure is highest for the manufacturer trade association where the desire will be to make sure that every member manufacturer has a significant product line that meets the standard. But even labeling systems independent of manufacturer control will grapple with the Three Bid Dilemma. If at least three different manufacturers don't have products to offer, specifiers running up against the omni-present competitive bid clauses will need to drop the label specification to get sufficient bid opportunities. Label makers will then be pressured to lower their standard until enough manufacturers can meet it or risk irrelevancy. However, with a lower standard in place, manufacturers then have little incentive to improve products beyond the standard. The ideal of protecting health and the environment collides with the reality of the current state of the market and of technology.

Most standards are stuck in this tension between a "good enough" level of protection and the realities of current product availability and manufacturer interests, seeking the perfect compromise threshold of something that is less bad than the status quo. Marshalling market forces for the continuous improvement necessary to drive products toward truly sustainable thresholds will require something more ambitious than seeking the minimal attainable level defined by what products are on the market now (and manufacturer pressure). An alternate approach that encourages continual market movement is to start not with where the technology and market are, but rather with where they need to go and then establish a roadmap to measure progress and provide incentives. In this scheme we would define the environmental performance attributes of ideal products in the future for true sustainability and then establish tiered thresholds and incentives between current technology and that ideal. We see the beginnings of this in various multi-level rating systems such as the California Gold Carpet Standard that set increasingly higher bars to rate progress toward increasingly improved product profiles. Continuous improvement is rewarded with higher point totals.

Even in this program, however, the pressure for continuous improvement is removed before you even get two-thirds of the way to the standard's 113 point ideal. Once the product meets the Platinum level of 71 points, attaining any of the extra points beyond that gains no marketable benefit. In fact, a manufacturer that attains the Gold level of 52 points for its carpet (less than half the optimal) can rest there. They have made the threshold for California State purchases and until they can improve by over one-third and make the leap to 71 points they will remain an undifferentiated Gold to the rest of the market. The standard says that "the carpet manufacturer shall provide metrics that demonstrate the specific achievement level and shall make these metrics publicly available" [9]. But neither the State nor the SCS website even reveal the point total that the carpet attained, much less what particular metrics helped it get there.

Pharos: Mapping the Future of Standards

The Pharos Project is a new effort by the Healthy Building Network to make sense of the chaos of the green building material market by modeling a comprehensive strategic approach to the evaluation of products. It addresses the questions raised above by proposing a comprehensive definition of a truly healthy, sustainable, socially just product, identifying the attributes that make up that ideal definition, and establishing benchmark steps toward that ideal. This framework can then be used to put the existing piecemeal patchwork of standards and labels into a context, making visible what piece of the puzzle each standard offers in the whole picture of sustainability. It works from the premise that designers, specifiers, and buyers will use a comprehensive but easy to understand system of analysis like this to guide specifications, purchases, and feedback to manufacturer's representatives to encourage a steady process of continuous improvement in products across the whole range of attributes toward the ideals.

The Pharos Project is made up of four major elements:

- Framework—A framework of analysis that establishes 16 categories of issues of concern, such as climate change and IAQ. It defines ideal goals in each category, establishes ten metric steps mapping progress toward that ideal and identifies how the attributes of a product can be used to score that progress.
- Product Database—A listing of building products and their attributes such as recycled content or embodied energy content.
- Label—An equivalent to the food nutrition label that provides graphic and textual ways to describe the result of applying the Pharos Framework to rate a product's progress toward the Framework ideals.
- Forum—A public forum that provides users a venue to discuss the definitions of the issues of concern, the framework of analysis and the products and manufacturers themselves.

Pharos Framework

The Pharos Framework expands beyond the traditional LCA impact categories in an effort to be more fully comprehensive of the whole range of concerns of health, environment, and social impact—including some which don't make it into LCAs if for no other reason than that they are difficult to quantify.

The Framework currently defines a set of 16 categories of concern in three major sectors:

- Health and Pollution
  IAQ/User Exposure
  High Hazard Toxics
  Global Warming
  Air Quality
  Water Quality
- Environment and Resources
  Embodied Energy
  Renewable Energy
  Embodied Water
  Sustainable Material
  Solid Waste
  Habitat
- Social and Community
  Occupational Safety
  Consumer Safety
  Fairness and Equity
  Corporate Leadership
  Community RelationsEach category is defined with five elements
- Intent
- Ideal
- Indicators
- Scoring Criteria
- Standards and Certifications

Intent

The intent statement defines the problem addressed by that category and the type of changes in building material impacts that are rewarded by this category. In the IAQ/User Exposure category, the intent describes the various chemical hazards to which building occupants are exposed, and identifies that the category rewards both elimination of content and emissions that may directly endanger the health of occupants of the building and those in its vicinity.

Ideal

Attributes of an ideal product are defined for each category, setting the goal for the category. For IAQ/User Exposure this goal is that there is no content in the product or material, nor measured emission from the product, of a hazardous chemical. This is truly an aspirational ideal against which to measure progress, not constrained by currently available technology and economics.

Indicators

Indicators questions establish the attributes that form the basis of the category scoring. For IAQ/User Exposure, this includes questions both about VOC emissions that users could be exposed to by breathing of emitted gases and about toxic chemical content that users could be exposed to through other pathways (dermal contact, breathing of dust, etc). Indicator questions also will include existing certifications that address these issues.

Scoring Criteria

For each category a ten-step progression is established between a worst case set of material indicators and the ideal, with criteria to satisfy at each step to progress. In some cases, the criteria represent thresholds to be attained. An example of this in the IAQ/User Exposure category is a limit that no VOC concentrations may exceed one-half of the chronic exposure level (CREL) established in the emission testing protocol established in the California 01350 VOC emissions standard. In other cases, a point system is used to establish a score. Again in IAQ/User exposure, points are gained by products that avoid certain common key hazardous contents of concern, such as formaldehyde and halogenated flame retardants.

Standards and Certifications

The Pharos Project is not designed necessarily to replace existing standards and labels, but rather to put them in context of the comprehensive picture of health, environmental and social impacts. Indeed Pharos can be most meaningful where third party certified data—as some standards and labels provide—can be utilized to verify attributes measured in Pharos. This section of the category describes how certification and labeling programs relate to the Pharos framework and scores. Programs are assessed to determine what attributes they verify, what thresholds they establish and hence what Pharos scoring level a product would attain if certified by the program.

Product Database

A database of building material products is being built that will catalog information about the attributes needed to describe the product and for scoring in the Pharos Framework, modeling the approach described in this paper. Data on products may be provided by users, such as designers or specifiers, or by manufacturers or may be obtained by staff from web listings. Industry average data may be used to estimate impacts when actual product specific data is unavailable. The University of Tennessee Center for Clean Products is developing protocols for data management and screening. Each data submission is tagged for its source and quality. Lower quality estimated or manufacturer claim data points are systematically replaced with higher quality independently verified data points as they become available.

Listings of products will be searchable in a variety of ways. Pharos system will then provide chart style reports for comparison of product attributes a graphic display of the scores in each category (Fig. 2) and a nutrition style label for graphic display of scoring and attribute information to encourage understanding of performance on the whole range of issues and weigh tradeoffs. The user will be able to drill down to see the data behind the scores and observe and evaluate the sources of data for a product assessment.

Transparency and Participation

Each aspect of the Pharos Project is considered open source—the Framework, the product database, and the labels and charting systems for communicating about them. Key for the project is to model transpar-

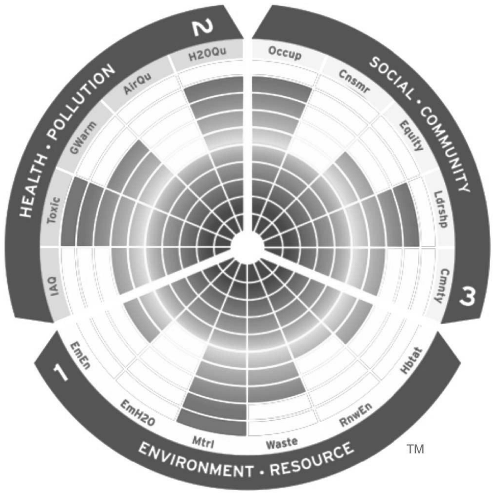


FIG. 2—*Graphic of Pharos lens showing scoring of different impact categories.*

ency in functionality, data and scoring systems, making clear the protocols used for establishing the evaluation system and opening to public scrutiny all of the data submitted and sources that drive individual product assessments. The project also encourages user engagement in discussing the assessment of products and their manufacturers and in future development of the Pharos framework and tool. A Forum of wikis, listserves, and other interactive technologies are used to support explanation of and user discussion about the health, environmental and social issues addressed in Pharos, the specific products listed and the manufacturers who produce them.

With the help of an advisory board of experts in the field, the project will seek to be continuously responsive to user input and engage in a continual reflection on the evolving science of impacts and the changing strategic opportunities to leverage change in the market toward ideals. In so doing the project is designed to model the aspirational goal setting process outlined above and help facilitate the transition of the label and standard industry into the market transformation actor needed to address the critical environmental problems we face.

Conclusion

The scale of change required to solve climate change, the challenges of persistent bioaccumulative toxic chemicals, and other serious health and environmental challenges calls for bold leadership from the labels and standards community. Strategic goal setting, comprehensive scope, accounting for uncertainty and data gaps, transparency, and continuous improvement oriented designs are needed to make labels and standards be effective market transformation tools. The Pharos Project seeks to model this approach with a goal-oriented, strategic perspective that places existing labels and standards in a comprehensive roadmap to material performance ideals to encourage the innovation and continuous improvement necessary to solve these environmental challenges and guide the way to a healthy, sustainable, and socially just material economy.

References

[1] Welshons, W., Thayer, K., Judy, B., Taylor, J., Curran, E., and vom Saal, F., "Large Effects from Small Exposures. I. Mechanisms for Endocrine-Disrupting Chemicals with Estrogenic Activity," *Environ. Health Perspect.*, Vol. 111, No. 8, 2003, http://www.ehponline.org/members/2003/5494/5494.html viewed 11/28/07. For a more complete discussion of this phenomenon, see "Our Stolen

Future, Myths: Industry Challenges to vom Saal," webpage of OurStolenFuture.org, http://www.ourstolenfuture.org/Myths/vomsaal.htm, viewed 4/12/07.

[2] Rajapakse, N., Silva, E., and Kortenkamp, A., "Combining Xenoestrogens at Levels Below Individual No-Observed-Effect Concentrations Dramatically Enhances Steroid Hormone Action," *Environ. Health Perspect.*, Vol. 110, No. 9, 2002, at http://www.ehponline.org/docs/2002/110p917-921rajapakse/abstract.html viewed 11/28/07. For a more complete discussion of this phenomenon, see "Our Stolen Future, New Science: Mixtures of Chemicals," webpage of OurStolenFuture.org, http://www.ourstolenfuture.org/NewScience/synergy/synergy.htm, viewed 4/12/07.

[3] Walsh, B., "The Label Game," *Healthy Building News*, Healthy Building Network, June 29, 2006, http://www.healthybuilding.net/news/060629labelgame.html, viewed 4/12/07.

[4] Consumer's Union Eco-Labels website, http://www.eco-labels.org/good_ecolabel.cfm, viewed 4/12/07.

[5] "USGBC Climate Change and Green Building," webpage of U.S. Green Building Council, http://www.usgbc.org/DisplayPage.aspx?CMSPageID=1618, viewed 4/12/07.

[6] Phthalate emissions from PVC building materials have been correlated with asthma and other bronchial challenges. For example, Jaakkola, J., et al. "Interior Surface Materials and Asthma in Adults: A Population-Based Incidence Case-Control Study," *Am. J. Epidemiol.* Vol. 164, 2006, pp. 742–749, http://aje.oxfordjournals.org/cgi/content/abstract/164/8/742 viewed 11/28/07 and linked with obesity and insulin resistance. For example Stahlhut, R., et al., "Concentrations of Urinary Phthalate Metabolites are Associated with Increased Waist Circumference and Insulin Resistance in Adult U.S. Males," *Am. J. Epidemiol.*, Vol. 115, No. 6, 2007, http://www.ehponline.org/docs/2007/9882/abstract.html viewed 11/28/07 More information about phthalates and potential health issues can be found at http://www.pharosproject.net/wiki/index.php?title=Phthalates

[7] Lent, T., "Toxic Data Bias and the Challenges of Using LCA in the Design Community," *Proceedings of GreenBuild Conference*, Pittsburgh, PA, Nov. 12–14, 2003, U.S. Green Building Council, Washington, DC, and in *Sustainable Development and Society*, U.S. General Services Administration, Washington, DC, October 2004, http://www.gsa.gov/graphics/ogp/SUSTDEVELOPMENTANDSOCIETYACCESSIBLEVERSION.doc viewed 11/28/07.

[8] "Assessment of the Technical Basis for a PVC Related Materials Credit for LEED," U.S. Green Building Council, February 2007, http://www.usgbc.org/DisplayPage.aspx?CMSPageID=1633, viewed 4/12/07.

[9] "California Gold Sustainable Carpet Standard," California Department of General Services, http://www.green.ca.gov/EPP/standards, viewed 4/12/07.

Journal of ASTM International, Vol. 4, No. 7
Paper ID JAI101072
Available online at www.astm.org

Jane M. Wilson[1] *and Jaclyn M. Bowen*[1]

Development of American National Standards for Sustainable Building Products

ABSTRACT: Numerous interior furnishing products have been introduced into the market claiming a variety of environmental attributes. End users are requesting access to information other than marketing claims to help understand the environmental benefits of each product and to be able to compare products using a consistent basis of measurement. Developing responses to these requests is time-consuming and expensive for manufacturers. Having a consensus set of attributes that define and identify sustainable products in the form of American National Standards will assist both manufacturers and end users in communicating environmental and sustainability related product benefits. NSF International, an ANSI-accredited standards development organization, is working with stakeholders in the contract textile, carpet and rug, and resilient flooring sectors to initiate separate sustainability standardization efforts for these product categories. By working with multiple industries that affect the indoor environment, NSF intends to promote the sharing of best sustainability practices across standards committees, so that the standards are developed in a consistent and cohesive manner. Establishment of these standards will serve to directly support and inform the end user decision-making process for the evaluation of products in these categories with respect to identifying the desired sustainability performance for products to be utilized within specific indoor environments.

KEYWORDS: sustainability, sustainable building products, carpet, textiles, resilient flooring, office furniture, business furniture

Introduction

Manufacturers of products used to furnish offices, schools, hospitals, hotels, restaurants, and other commercial and institutional indoor environments find themselves needing to respond to a variety of emerging market drivers that include:

(1) Federal, state, and local environmentally preferable purchasing and procurement practices;
(2) Growing influence of the U.S. Green Building Council [2] and its Leadership in Energy and Environmental Design (LEED) [3] green building standards;
(3) Demand and interest from the architecture and design community and other consumers for sustainable products; and
(4) Product manufacturers and suppliers who have instituted rigorous product stewardship programs.

For example, the contract textile industry has become one of the primary centers of activity for the "sustainable design" dialogue. Numerous textile products have been introduced into the market claiming a variety of environmental attributes. Textile end users are requesting access to documented information other than marketing claims to help them in understanding the environmental benefits of each product and in comparing products using a consistent basis of measurement. It is a challenge for designers and manufacturers because end users are often requesting this information in very diverse formats. Different end users value different sustainable product attributes and the information requests are inconsistent. The result is that manufacturer responses to these requests are time-consuming and expensive. A consensus set of attributes that define and identify sustainable products such as contract textiles would assist both manufacturers and end users in communicating environmental and sustainability related product benefits using consistent terminology and metrics.

NSF International is also working with stakeholders in the carpet and rug and resilient flooring product sectors to initiate separate sustainability standardization efforts for these product categories. NSF is also working with the Business and Institutional Furniture Manufacturers Association (BIFMA) [4] to support the establishment of a BIFMA sustainability standard for the office and institutional furniture sector. By

Manuscript received February 19, 2007; accepted for publication June 26, 2007; published online August 2007.
[1] Director of Standards and Standards Specialist, respectively, NFL International, 789 N. Dixboro, Ann Arbor, MI 98105.

working with multiple industries that affect the indoor environment, NSF intends to promote the sharing of best sustainability practices across standards committees, so that the standards are developed in a consistent and cohesive manner. Establishment of these standards will serve to directly support and inform the end user decision-making process for the evaluation of products in these categories with respect to identifying the desired level of sustainability performance for the product's specific end use application.

Who is NSF International?

NSF International (NSF) is a not-for-profit, nongovernmental, third-party organization, and is a leader in standards development, product testing and certification, education, and risk management for the protection of public health and safety. For more than 60 years, NSF has been committed to public health, safety, and protection of the environment. While focusing on the protection of food, water, indoor air, and the environment, NSF develops consensus national standards, creates learning opportunities through its Center for Public Health Education, and provides third-party conformity assessment services, while representing the interests of all stakeholders. The primary stakeholder groups served by NSF include the regulatory community, industry, product users, and the general public. NSF is recognized for its scientific and technical expertise in the health and environmental sciences. Its professional staff includes engineers, chemists, microbiologists, toxicologists, and environmental health professionals with broad experience both in public and private organizations.

By establishing an open, transparent, and unbiased forum for standards development, NSF has provided public health and safety leadership that has culminated in the development of more than 50 American National Standards. NSF's standard development process is accredited by the American National Standards Institute (ANSI), which requires openness and due process in the development of consensus standards. Any interested stakeholder has the right to due process, which includes stating a position, having that position considered, and appealing procedural actions or inactions of a standards committee. NSF's standards process consists of volunteer committees where technical and scientific discussions of interested stakeholders form the basis for developing consensus standards.

The NSF standards development process includes the following major actions:

- Public announcement of the new standards development activity and the formation of a new standards committee in ANSI *Standards Action* online newsletter and other suitable media (e.g., press releases, website postings, etc.). This action communicates the purpose and intent of the standards development effort to the interested public.
- Interested stakeholders are requested to submit applications to serve on the standards committee, prior to formation of a balanced standards committee to undertake the standards development effort.
- The standards committee drafts the proposed voluntary consensus standard(s) during regularly scheduled meetings and teleconferences. The standards committee may form subgroups to work on specifications for individual topic areas covered by the standard(s).
- When completed, draft standard(s) is(are) balloted by the standards committee. Simultaneously, a request for public comment on the draft standard(s) is(are) submitted for publication in ANSI *Standards Action*, ensuring that any additional interested stakeholders have the opportunity to review the draft standard and provide comments. The public comment period may also be announced through other media.
- Any views and objections identified through the standards committee ballot process and the public comment process must be reviewed and addressed by the standards committee.
- The standard is finalized once all views and objections and any subsequent appeals have received due process, and the standards committee documents the achievement of a consensus decision (as defined by NSF Standards Development and Maintenance Policies [1]).
- A notification of final action for completion of the standard(s) is submitted to ANSI for publication.
- The resulting standard(s) is (are) publicly accessible for use by product manufacturers, conformity assessment organizations, interior design professionals, governmental procurement agencies, product distributors and retailers, and any other interested users.
- The resulting standard(s) must also be maintained according to ANSI procedures, which require revision or reaffirmation of the standard at a minimum of every five years.

Why Develop Consensus Standards for Sustainable Products?

The development of voluntary consensus standards will provide consistent tools to help purchasers, specifiers, and other end users understand how to evaluate and compare products with multiple environmental and sustainability related attributes. Transparency, consensus, and accountability in the development of standards are achieved through an ANSI-accredited organization required to use an open and transparent stakeholder consensus process with numerous opportunities and formats for stakeholder input. ANSI standards can be used as tools for first-party (self), second-party, or third-party (independent) certification and are accessible to all potential end users.

Since many specifiers and purchasers value third-party certification, the benefit of an American National Standard is that any qualified third party can certify products against the standard. In contrast, ecolabels, which are proprietary labeling systems typically developed by nongovernmental organizations, are sometimes perceived negatively because the marketplace uses them as de facto standards, despite the fact that they are often developed in the absence of an open consensus process. In the U.S., the National Technology Transfer and Advancement Act (NTTAA) directs Federal Government agencies to achieve greater reliance on voluntary consensus standards developed by the private sector and decreased reliance on standards developed by and for the government. It also directs that Federal agency personnel participate as appropriate in the activities of voluntary consensus standards developing organizations to help ensure that standards produced in the private sector are more likely to be appropriate for use by Federal agencies. Specific to the area of sustainability, Executive Order 13423 Strengthening Federal Environmental, Energy, and Transportation Management [5] was signed in January 2007 and requires Federal agencies to "…conduct their environmental, transportation, and energy-related activities under the law in support of their respective missions in an environmentally, economically and fiscally sound, integrated, continuously improving, efficient, and sustainable manner."

By establishing voluntary national standards, the market will help determine what type of certification is sought by product manufacturers based on end-user needs. Manufacturers will likely have several qualified certifying organizations from which to choose, which in turn helps to keep certification costs competitive. The specifying community (e. g., architects, designers, commercial, and government procurement officers, etc.) will have a means of comparing sustainable products using standards that provide evaluation criteria and metrics consistent with the intent of Executive Order 13423, Executive Order 13101 Greening the Government Through Waste Prevention, Recycling, and Government Acquisition [6], and the U.S. Environmental Protection Agency's Environmentally Preferable Purchasing (EPP) Guiding Principles [7].

The establishment of specific sustainable product attributes that encourage reduction of the content of toxic and bioaccumulative chemicals, or both, will improve air emissions, quality of local waterways, and worker protection over time from reduced toxicity of materials in the communities where facilities producing sustainable products are located and operate.

Establishing raw material and toxicity requirements for products used in the indoor environment will have multiple benefits:

- Improved indoor air quality within the built environment (e.g., commercial, government, healthcare, schools, and hotel/hospitality);
- Reduced toxicity from agricultural sources of pollution (especially for those products meeting organic or sustainably managed agricultural resources);
- Reduced toxicity from manufacturing discharges, especially for aquatic environments from improved water quality;
- Lower costs for recycling and refurbishing for products having lower content of toxic chemicals; and
- Greater resource conservation due to emphasis on efficient use of materials, incorporation of recycled content, greater reliance on renewable resources, and thoughtful design for reusability and recyclability.

It is intended that the standards will include metrics addressing the direct or indirect use of renewable energy sources (i.e., tradable renewable energy credits[2]), which will help to stimulate the market for

[2]Manufacturers and other businesses interested in promoting the development of environmentally friendly sources of power who want to offset their energy conventional usage can purchase renewable energy credits, or RECs, from producers of green power. The primary sellers of RECs are

renewable sources. The standards can also serve as templates for additional product sectors so that stakeholders can concentrate on the sustainability issues that are particular to their specific products and end uses.

Sustainable Textiles

In 2004, the Association for Contract Textiles (ACT) [8] formed a partnership with the GreenBlue Institute (GreenBlue) [9] with a goal of creating a "community of practice" within the contract textile industry. The purpose of this effort was to provide practical guidance to the contract textile industry about how to design and manufacture "sustainable" textiles. In 2005, ACT and GreenBlue invited NSF International to join the project as the accredited standards development organization to transition the goal from creating a community of practice to establishing a consensus national standard for sustainable textiles. The primary purpose of this partnership is to drive the development of a standard for the manufacturing of sustainable textiles within the contract textiles sector in accordance with the requirements of the American National Standards Institute (ANSI). NSF has created an American National Standard project through ANSI, and the standard will be identified as NSF 336 Sustainable Textile Standard. Ideally, the standard will serve two purposes:

(1) Create a resource for the contract textile industry that provides as much guidance and information as practicable to inform manufacturers and end users about the elements of sustainable design and manufacturing of textiles and responsible product stewardship practices; and
(2) Provide a transparent and fair means of assessing textile products claiming to have sustainable attributes. The goal is to create a standard with metrics that are relevant, measurable, and economically feasible, including a mechanism for recognition of innovative approaches to production of sustainable textiles. It is also important that the standard define a reporting format that is easily understood by end users so product-to-product comparisons can easily be made.

In January 2006, NSF convened the first meeting of interested sustainable textile stakeholders to discuss the scope and breadth of the proposed standard. The stakeholder group is made up of volunteers from industry, academia, Federal and state government, the design community, and nongovernmental organizations who have particular expertise or who are interested in understanding how textile manufacturers can become better stewards of their products. Based on the research and development of a draft guidance document prepared by GreenBlue in 2003–2004, the stakeholder group has organized its efforts around the following core categories for developing the sustainable textile standard's metrics—Fiber Sourcing, Safety of Materials, Water Conservation, Water Quality, Energy, Recycling and Reutilization Practices, Social Accountability, and Innovation. For each of these topic areas, smaller groups of stakeholders having expertise in the specific subject matter are meeting to design the requirements for that section of the sustainable textile standard.

The proposed Fiber Sourcing requirements provide recognition of practices such as the use of fibers from rapidly renewable resources, fibers produced through organic or transitional organic processes, fibers produced using integrated pest management principles, fibers from bio-based processes, and fibers having recycled content. For Safety of Materials, an inventory of all intentionally added chemicals to the level of 1000 ppm (0.1 %) is required, and the inventory must be assessed for the presence of chemicals of toxic concern, such as carcinogens and reproductive toxicants. Water Conservation criteria include evaluation of water usage versus industry baselines and the implementation of specified water conservation techniques in manufacturing and facility management operations. The Water Quality elements seek to establish routine monitoring of and improvement in water quality released from manufacturing processes. The Energy Requirements encourage manufacturers to document the amount of energy needed fro production of the sustainable product. Additional requirements include performance of an energy audit and the offset of energy usage with renewable energy sources. Recycling or reutilization practices that reduce the consumption of virgin materials are recognized in the Recycling section. Product design is also considered, when it can be demonstrated that the textile product has been designed to facilitate recycling at end-of-life or has a program to reclaim its products from end users. The Social Accountability criteria focus on the protection of basic human rights of workers in the textile industry, and utilize widely accepted International Labor

"green" energy producers who generate power from such sources as wind, biomass, hydroelectric, and solar energy plants. When RECs are traded, the entity purchasing the REC gains the right to claim the environmental benefits.

Organization (ILO) conventions as their basis. Lastly, Innovation is recognized in textile manufacturing for documented sustainable achievements that are not specifically included in the standard, or that go significantly beyond the required level of achievement specified in the standard.

Sustainable Carpet

In addition to helping create a standard for the textile industry, NSF has initiated a project to establish an ANSI standard for sustainable carpet and rugs. In 2005, the Carpet and Rug Institute (CRI) [10] asked NSF to become the ANSI secretariat for a sustainable carpet standard developed by the carpet and rug community and other stakeholders under another consensus process. For several years, CRI's membership and other stakeholders had worked with the Institute for Market Transformation to Sustainability (MTS) [11] to establish a standard for sustainable carpet products. Upon completing the standard, CRI sought to establish the standard as an American National Standard. CRI and MTS agreed to place the standard in the public domain, and NSF agreed to act as the ANSI secretariat for the standard.

Since a well-developed document was already available, NSF registered the existing standard with ANSI under an option known as Draft Standard for Trial Use. Under the identifier Draft Standard for Trial Use NSF 140—Sustainable Carpet Assessment Standard [12], the standard has been registered for a trial use period not to exceed three years, during which a standards committee established by NSF will review the standard and refine its requirements. During the trial use period, the draft standard can be used for conformity assessment purposes, and feedback from manufacturers and end users will be provided to the standards committee to consider in the process of reviewing the current requirements. This provides a mechanism for assessing specific problems identified in the implementation of the Draft Standard while the standards committee is finalizing the specific requirements. The State of California is utilizing the NSF Draft Standard as the basis of its state requirement for the purchase of environmentally preferable carpet products, known as California Gold [13].

The first meeting of the carpet standard committee took place in May 2006. Like the contract textile committee, the primary focus of the committee's activities to date has been to direct and manage smaller groups of stakeholders in the review and refinement of the specific areas of achievement already defined by the standard, and to determine if additional sustainability criteria should be identified and developed for this industry.

The NSF 140 draft standard addresses the following areas of sustainable performance for carpet and rug products: Safe for Public Health and Environment, Renewable Energy and Energy Efficiency, Materials, Manufacturing, Reclamation and End of Life Management, and Innovation. Each area of sustainable performance has defined prerequisite achievements that a product must meet in order to comply with the standard. Additional achievements beyond the prerequisites are awarded defined numbers of points. The total number of points awarded to the product defines one of four levels of sustainable performance recognized by the standard. The standard also allows for innovation points to be awarded for areas of achievement not defined by the standard, or for achievement exceeding the defined levels of performance included in the standard.

The Safe for Public Health and the Environment category addresses the need for carpet manufacturers to inventory material composition for components present at 1 % or greater of the final product. It also includes assessment of emissions and pollutant discharge reductions against baselines. Indoor Volatile Organic Compound (VOC) emission performance of the carpet product is also assessed. Energy impacts are assessed through recognition of energy inventory, greenhouse gas emissions reduction, use of renewable energy and implementation of energy conservation and energy efficiency measures. Materials usage includes assessment of the use of bio-based, recycled, or other environmentally preferable materials. Elements of this criterion include a materials inventory and documentation of the environmentally preferable product content. The Manufacturing criteria include assessment of the corporate commitment to environmental responsibility and social indicator reporting. These criteria include utilization of Life Cycle Assessment and Design for Environment principles. Reclamation and End-of-Life Management is intended to encourage product reuse and reclamation programs in order to reduce waste to landfill and incineration. For Innovation, specific recognition of dematerialization (providing equal function using less material) is defined, as well as recognition of innovative practices beyond those defined in the draft standard.

Business and Institutional Furniture

BIFMA International is the major trade association for business and institutional furniture and is also an ANSI-accredited standards developer. The organization's membership endorsed the concept of developing a consensus standard for sustainable business furniture in 2005, and BIFMA organized its first stakeholder meeting in early 2006. NSF was invited to participate as a stakeholder, since its work with the textile industry has some bearing on that component of sustainable furniture. BIFMA and NSF eventually created a partnership whereby NSF would be the ANSI secretariat for the BIFMA standard, and the standard would be developed in accordance with NSF's accredited procedures. This partnership enables the BIFMA standard project to benefit from the experiences of the other NSF sustainable product standards committees, and has allowed for close communication between the furniture and textiles industries with respect to their goals for achieving sustainability. Areas of sustainability being addressed by the BIFMA standard include Human and Ecosystem Health, Energy, Materials, and Social responsibility.

The Human and Ecosystem Health area focuses on effective management of chemical inputs and outputs, as well as recognition of efforts to reduce toxic chemicals of concern currently used in manufacturing processes. It also includes reduction of hazardous emissions and wastes, both from the manufacturing process, and emissions from the finished products in their end use environment.

The Energy requirements of the BIFMA standard include the conduct of a facility energy inventory, assessment of the embodied energy of raw materials and other components, participation in Energy Star programs, and reduction of energy use in material and product transportation and facility operations. It also proposes support for the inventory and reduction of greenhouse gas emissions associated with product production and transport.

The Materials section encourages to the use of Life Cycle Assessment to optimize the product design and materials selection processes. It also recognizes materials use efficiency, employment of bio-based renewable materials, recycled content, use of recyclable and biodegradable materials, and other end-of-life management options such as reuse and remanufacturing.

For Social Responsibility, baseline requirements include ensuring worker health and safety and acknowledgement of the basic rights of workers at the local, national, and global levels. Promotion of diversity, community outreach and involvement and social responsibility reporting are additional aspects defined by the BIFMA standard.

The draft BIFMA standard has undergone an informal public review by interested stakeholders, and several furniture manufacturers conducted pilot assessments of their own products in order to provide detailed comments and feedback on potential improvements. Those comments are now being reviewed and considered by the consensus body for further revision of the draft document.

Resilient Flooring

NSF has been contacted by the Resilient Floor Covering Institute (RFCI) [14] about developing an ANSI standard to address sustainability issues for this industry, which produces flooring products from vinyl, linoleum, cork, etc. RFCI intends to use a development model similar to that being followed for the carpet and rug industry, with the registration of a Draft Standard for Trial Use followed by initiation of the consensus standards process. NSF has announced this effort as an ANSI standards project and expects to convene the initial standards committee meeting during 2007. RFCI stakeholders are in the process of preparing the draft standard for submittal to NSF. The work completed to date for the textile, carpet and rug, and business furniture industries will serve to inform the development of this sustainable product area as well.

Coordination across Standards Committees

While each sustainable product standards project undertaken by NSF has resulted in the formation of a separate consensus body, it was recognized that the separate committees would benefit from the creation of a forum that would provide an opportunity to communicate on common issues. Volunteers from each stakeholder group have been meeting to discuss the common challenges to their standards projects and to identify options and potential resolutions to specific issues that have been raised by the project participants. Common issues being discussed are briefly reviewed here.

Establishment of meaningful, auditable criteria for social and corporate responsibility that will not represent an undue financial burden on companies seeking compliance to the standards has presented a challenge. While a recognized standard for social accountability, SA8000, exists, it represents a significant financial investment on the part of the company seeking compliance.

The merit of different models for evaluation systems is another topic that has been explored. An evaluation system that results in pass/fail of a product is less confusing to end users than a system that allows for recognition of multiple levels of sustainable achievement of a product, but having multiple levels of achievement can provide for a standard that is accessible to a greater portion of the affected industry. Multiple levels of achievement can also provide incentive for continuous improvement of products, by providing direction to manufacturers on what additional measures they can undertake to raise their sustainable performance. Corporate-level sustainability achievement versus product-level sustainability achievement has also been discussed across the standards projects. All of the draft standards contain a combination of elements that recognize corporate level activities, such as having a corporate environmental policy, as well as product level achievement such as reduction of a toxic chemical used in a product formulation.

All of the draft standards include a mechanism for the recognition of innovation in sustainable performance, but common concern exists regarding how to evaluate innovation in a consistent fashion, particularly if multiple third parties offer assessment service to one standard. The consensus bodies are looking to the precedent provided by the LEED standards in how to define what is an innovation, and in how to provide sufficient structure in the standard to result in consistent interpretation and recognition of innovative approaches.

Another common challenge has been to ensure that the overall requirements of the standard do not favor one type of manufacturing or production model over another. Vertically integrated manufacturers, those having management and operational control over their upstream and downstream supply chains, can be disadvantaged as compared to other production models. The disadvantage would come from having to determine the sustainable footprint of all the manufacturer's operations, as opposed to a company that assembles components manufactured by independent suppliers that are not part of its core operation. A related issue has been defining the boundaries of the standards which respect to how much of the manufacturer's supply chain should also be subject to assessment in determining the sustainable achievement of the manufacturer.

By providing a vehicle for cross-committee communication, NSF seeks to have its various committees share best practices, which may help accelerate the standards development process to its conclusion.

Challenges in the Standards Development Process

One of the challenges faced by the NSF standards committees has been the recruitment of members of the nongovernmental organizations (NGOs), academic and design communities who have both the desired expertise in sustainable product issues, and the time and financial support to volunteer their efforts to a standards development project. Initial standards writing efforts are time and resource intensive, and in today's economic and business climate, it is increasingly challenging to find volunteers who can obtain permission to devote the time required for an uncompensated activity. NGOs are sometimes reluctant to participate directly in standards efforts, as while the NGO may support the concept of the creation of a standard, it may be adverse to the perception of having endorsed a specific standard and lessening its organizational impartiality. By primarily using teleconference meetings and web-based media for the distribution and review of materials, NSF has been able to recruit an adequate number of volunteers; however, efforts will continue to identify others in the NGO, academic and design communities that are willing to contribute to these projects.

NSF is also challenged to ensure that the output of the several standards committees has a consistent format and presentation. For the industries with which NSF is working, the proposed standards are anticipated to define several levels of sustainable achievement. This multi-level approach is consistent with that established by the LEED standards. However, different committees are considering slightly different classification systems, and may vary in the number of levels of achievement recognized in the standard. It is also desirable that the various classification systems capture consistent levels of effort that will be required across the various industries to achieve what may be labeled as the same level of sustainable achievement amongst the different standards. For instance, a "gold" level of achievement for a textile product should be similar to a "gold" level of achievement for a piece of furniture.

Coordination and Collaboration among Standards Developers

NSF is not the only ANSI-accredited standards developer active in the area of sustainability. ASTM International has been a standards development leader in this area for several years. As previously mentioned, BIFMA International is an accredited standards developer in its own right. More recently, organizations such as the Green Building Initiative (GBI) [15], GREENGUARD Environmental Institute (GEI) [16], Leonardo Academy (LEO) [17], Institute for Market Transformation to Sustainability (MTS), and the U.S. Green Building Council (USGBC) have become accredited as well. Many of these organizations have already announced standards projects addressing various aspects of sustainability and sustainable product design and manufacturing. Given the breadth and number of potential opportunities for standardization in the area of sustainable products and services, coordination and collaboration among these different organizations is desirable, to avoid the development of duplicative and/or conflicting requirements.

Development of standards within the ANSI community helps to ensure that duplicative and conflicting work is not undertaken. ANSI-accredited standards developers are required to provide adequate notice of the standards development activities they are undertaking. At a minimum, this requires the submittal of a Project Initiation Notification (PIN) to ANSI describing new standards development activities. The PIN is published in ANSI's on-line newsletter, *Standards Action*, and allows for a 30-day public comment period. This provides the opportunity for any affected individual to comment on the proposed standards project, including comments related to potential duplication or conflict with existing or candidate American National Standards. When potential duplication or conflict is alleged, a mandatory deliberation of stakeholders is triggered, and the affected standards developers provide a report to ANSI on the outcomes of the deliberations.

Openness in the coordination of standards development processes also promotes development of standards that make the best use of the existing knowledge of sustainability. NSF has welcomed the participation of other standards development organizations among the stakeholders participating in its standards projects. These other standards organizations have actively contributed to NSF's standards process and have shared their own areas of sustainability expertise. This communication through standards processes will help to ensure that NSF standards are in alignment with other consensus sustainability standards, and that the work products of other organizations are appropriately referenced and utilized. Stakeholders that are active in multiple sustainability standards efforts have also been able to identify other standards that can be referenced within the NSF standards as tools for sustainability achievement. One such example is the ASTM International Committee E 06 work item titled WK 4879 Standard Practice for Assessing Environmental Performance Improvements of Electric Power Generation Facilities and Infrastructure [18], which, when finalized, can be a tool used by manufacturers to identify electrical power facilities that have achieved a level of environmental improvement for credit toward their own sustainability achievement.

Desired Outcomes for Sustainability Standards

NSF is anticipating these new sustainable product standards to be available for use in late 2007 or early 2008. A key outcome for determining the success of sustainability standards is the acceptance and implementation of the standards within the manufacturing and end user communities. The use of broad and diverse stakeholder groups with relevant expertise and a high level of commitment by industry, end users, academia, government, and non-governmental organizations leads to a robust result and a greater likelihood of acceptance of the standard by the target audiences. Another key outcome is an increase over time in the number of products that will be evaluated to the consensus criteria established in each standard. The ability to measure improvements that can be attributed to the standards will depend upon the number of companies that comply with each standard's requirements and the number of end users that specify implementation of the standards. This action will likely be started by individual companies publicly reporting their results and improvements as a means of differentiating their products in the marketplace. Over time, and as more information on individual products becomes available, organizations such as trade associations or third parties may be able to compile the results from multiple companies into reports that describe the sustainable improvements made by industries as a whole.

The purpose of creating standards with multiple sustainability attributes is to ensure maximum benefit to the environment across numerous media. Some of the most relevant measures for these industries are toxicity of chemicals and materials, types of energy used, water conservation and quality, conservation of natural resources, recovery and recycling of materials along the entire life cycle, and socially responsible manufacturing practices. Quantifiable verification of positive environmental and social results is possible using data from manufacturers that are compliant to sustainability standards once a statistically significant sample size becomes available over time.

Individuals interested in learning more about these sustainable standards projects are invited to contact Ms. Jaclyn Bowen at bowen@nsf.org.

References

[1] NSF International, Standards Development and Maintenance Policies, http://www.nsf.org/business/standards_and_publications/pdf/NSF_2004-policies.pdf (February 19, 2007).

[2] U.S. Green Building Council, http://www.usgbc.org (February 19, 2007).

[3] Leadership in Energy and Environmental Design (LEED) Standards, http://www.usgbc.org/DisplayPage.aspx?CategoryID=19 (February 19, 2007).

[4] BIFMA International (BIFMA), http://www.bifma.org (February 19, 2007).

[5] Executive Order 13423, "Strengthening Federal Environmental, Energy, and Transportation Management," http://www.whitehouse.gov/news/releases/2007/01/20070124_2.html (January 24, 2007).

[6] Executive Order 13101 of September 14, 1998, "Greening the Government Through Waste Prevention, Recycling, and Government Acquisition," http://www.ofee.gov/eo/13101.htm (February 19, 2007).

[7] U.S. Environmental Protection Agency, Environmentally Preferable Purchasing (EPP) Guiding Principles, http://www.epa.gov/epp/pubs/guidance/fivegp.htm (February 19, 2007).

[8] Association for Contract Textiles (ACT), http://www.contracttextiles.org (February 19, 2007).

[9] GreenBlue Institute, http://www.greenblue.org/ (February 19, 2007).

[10] Carpet and Rug Institute (CRI), http://www.carpet-rug.org/index.cfm (February 19, 2007).

[11] Institute for Market Transformation to Sustainability (MTS), http://mts.sustainableproducts.com/ (February 19, 2007).

[12] NSF International, Draft Standard for Trial Use NSF 140—Sustainable Carpet Assessment Standard, http://www.nsf.org/business/standards_and_publications/pdf/NSF_140-05-DS.pdf (February 19, 2007).

[13] State of California, Department of Health Services, "California Gold Sustainable Carpet Standard," http://www.documents.dgs.ca.gov/green/epp/standards.pdf (February 19, 2007).

[14] Resilient Floor Covering Institute (RFCI), http://www.rfci.com (February 19, 2007).

[15] Green Building Initiative (GBI), http://www.thegbi.com (February 19, 2007).

[16] GREENGUARD Environmental Institute (GEI), http://www.greenguard.org (February 19, 2007).

[17] Leonardo Academy (LEO), http://www.leonardoacademy.org (February 19, 2007).

[18] ASTM Standard WK 4879, "Standard Practice for Assessing Environmental Performance Improvements of Electric Power Generation Facilities and Infrastructure," http://www.astm.org/cgi-bin/SoftCart.exe/DATABASE.CART/WORKITEMS/WK4879.htm?L+mystore+tedd2095+1171922319 (February 19, 2007).

Journal of ASTM International, Vol. 4, No. 10
Paper ID JAI101081
Available online at www.astm.org

William H. Freeman[1]

FloorScore—Flooring Products Certification Program for Indoor Air Quality

ABSTRACT: The purpose of this paper is to provide information on the development of a volatile organic compound (VOC) emissions testing program for hard surface floor covering products. After providing historical information on the development of VOC emissions testing programs for interior finishes, the paper discusses the factors considered and steps taken by the Resilient Floor Covering Institute (RFCI) to design the FloorScore Indoor Air Quality (IAQ) Certification Program.

Introduction

Today, most sustainable building rating systems include requirements that address indoor air quality as a key issue for the health and comfort of building occupants. VOC emissions from building materials used as interior finishes, including floor coverings, can contribute to the quality of air in occupied buildings and have been the subject of considerable discussion during the past two decades.

History

In 1990, the U.S. Environmental Protection Agency (EPA) received a petition under Section 21 of the Toxic Substances Control Act (TSCA) from Local 2050 of the National Federation of Federal Employees to initiate rule-making proceedings to reduce emissions from new carpets. The petition focused attention on employees' concerns about the variety of health complaints claimed to be related to the emission of chemicals from newly installed carpet. EPA denied the petition on the basis that there was insufficient data to support the conclusions and remedies sought by the union. However, EPA stated that as a matter of policy, "it is prudent to minimize indoor human exposure to VOC's where reasonable." Thus, the Carpet Policy Dialogue [1] was initiated by EPA as a one-year process to clarify scientific issues about carpet emission concerns and to identify methods for improving indoor air quality. EPA's charge to the Carpet Policy Dialogue specifically stated: "The goal of the dialogue will be to characterize emissions and identify low impact, feasible VOC controls that could be implemented in the near term, not to further characterize the health effects of chemicals emitted from carpeting." Two significant results of this voluntary effort, which included government and nongovernment representatives as well as representatives from the carpet industry, were agreement on (1) an emissions test apparatus (small chamber), and (2) the decision to quantify the emissions as total VOCs (TVOC). The results of the Carpet Dialogue led to the decision by the Carpet and Rug Institute to introduce the Green Label program for testing VOC emissions from carpeting and labeling compliant carpet lines. This milestone program would eventually lead to VOC emissions reporting for other types of interior finishes.

Research

In addition to research in the United States on VOC emissions from building materials, European scientists were actively studying these emissions, especially in the Scandinavian countries. Much of this work in Europe was based on the theory that the lower the TVOC levels, the lower the potential health impact. The Swedish Flooring Association (GBR) together with Swedish National Testing and Research Institute de-

Manuscript received March 6, 2007; accepted for publication October 30, 2007; published online November 2007.
[1] Resilient Floor Covering Institute, Rockville, MD.

veloped a test method for chemical emissions from flooring materials (Swedish Trade Standard) in 1992 [2]. Today, resilient flooring being sold in Sweden must meet TVOC emission factors based on tests conducted at 4 and 26 weeks.

At Indoor Air'96, the Seventh Annual International Conference on Indoor Air Quality and Climate held in Nagoya, Japan, many of the sessions focused on indoor air quality problems around the world. During one session at the conference Lars Molhave, a respected European scientist and considered by many to be the "father" of the TVOC concept, cited the lack of consistent and conclusive results relating symptoms to TVOC levels despite ten years worth of case studies, research, and literature review. Among the reasons cited for this change in view were: (1) the lack of reliable health risk data on mixtures or synergistic effects of chemicals at the TVOC levels commonly found in buildings, (2) the lack of technology for accurately and economically measuring TVOCs in the environment on a real-time basis, (3) conflicting and confusing results from various studies looking at the relationship, and (4) the lack of existing building ventilation data for useful interpretation of the study results [3]. Furthermore, Dr. Molhave agreed with the report of twelve highly respected IAQ scientists who stated in their Nordic Scientific Committee report that "except in extreme cases, there is no scientific basis for the use of TVOC as a risk index for discomfort or for health effects in buildings" [4]. The group did say that the chemical composition of IAQ was very likely important for health and well-being and that continued research should be developed on more relevant measures of both exposure and effects. Thus, the growing consensus among the leading researchers in the field was that a TVOC measurement was not a useful indicator of the risk of health effects in indoor air and not a fruitful tool in determining the causes of Sick Building Syndrome symptoms. Agreeing with European scientists was the California EPA Integrated Waste Management Board, which stated in its November 2003, Building Material Emissions Study that "TVOCs cannot be used to indicate potential health effects" [5].

Testing for Vocs

In late 2000, RFCI engaged Berkeley Analytical Associates, LLC (BAA) in Richmond, California, to test and characterize the VOC emissions from resilient floor covering materials. Al Hodgson of BAA, who is recognized internationally as an IAQ scientist and has published extensive research papers on this subject, designed the emissions testing program. In the first round of the program, 51 different resilient flooring products including rubber, vinyl, vinyl composition, linoleum, and polymeric floors were tested for their emissions of individual VOCs. As a result of these tests, flooring companies substituted raw materials or changed manufacturing processes. Two additional rounds of emissions testing took place from December 2001 to July 2002 and included many of the same flooring products in the initial round of testing, as well as new product formulations which generated lower VOC emissions of targeted VOCs.

Increasing Requests for Emissions Data

Additional developments were also taking place which would eventually convince building product manufacturers of the importance of knowing what chemicals were being emitted from their products, including:

1. In 1995, the State of Washington established a Ventilation & Indoor Air Quality Code for use in designing and operating a new state office building. This document required building materials manufacturers, including those manufacturing resilient flooring, to comply with VOC emission rates in order to have their products specified [6].
2. In 2000, EPA issued its report on "Healthy Buildings, Healthy People—A Vision for the 21st Century." Under Goal #4 in the report, Create and Use Innovative Products, Materials and Technologies, EPA recommended that standardized, consensus-based generalized emissions testing programs be established with stakeholders so that the potential exposure and health risk of most consumer products and building materials could be assessed [7].
3. The State of California established environmental requirements for the Capital Area East End State Complex of State office buildings, including VOC emissions requirements for building materials as described in architectural specification "Section 01350, Special Environmental Requirements."
4. The California Integrated Waste Management Board conducted an extensive study comparing the VOC emissions from standard building materials versus building materials with recycled content.

One of the goals of the study was to investigate the applicability of Section 01350 as a screening tool for standard and alternative resilient flooring materials.

5. The California Collaborative for High Performance Schools (CHPS) developed its Best Practices Manual, which recommended that floor covering products specified for schools in California meet the VOC emission requirements in Section 01350. The CHPS Criteria rating system awarded points to school construction products that used compliant products in several categories including carpet and resilient flooring [8].
6. Green Building programs, including the U.S. Green Building Council's LEED rating system, began offering credits for low-emitting carpet products.

Resilient floor covering manufacturers monitored each of these developments. At the same time, the resilient flooring industry was receiving an increasing number of requests for resilient flooring VOC emissions tests of resilient floors from architects, specifiers, and building owners who wanted to compare the IAQ impact of resilient flooring with other flooring options, namely carpet. With the growing interest in VOC emissions from hard surface flooring, the Resilient Floor Covering Institute recognized there was a void in the marketplace as no available VOC emissions testing program focused on hard surface flooring.

Designing a VOC Emissions Testing Program

In reviewing the developments in VOC emission testing in prior years, the Resilient Floor Covering Institute concluded that IAQ testing programs in the future should have specific and rigorous requirements in order to be widely accepted in the marketplace, including: (1) focus on individual VOCs, and not TVOC, (2) VOC emission limits established by a governmental agency based on health risk assessments, (3) testing by recognized independent laboratories, (4) certification by an independent third party, and (5) transparent procedures available to the public [9].

With these requirements for developing an IAQ program for hard surface flooring it was a relatively easy decision to base the program on the Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers. This product testing practice, which is now commonly referred to as "California Section 01350" was developed by the California Department of Health Services IAQ research staff with input from other environmental scientists [10]. It is publicly available and follows the guidance of ASTM D 5116 for small-scale chamber testing of products. It details the procedures required to test product samples, including hard surface flooring, for their emissions of individual VOCs in environmental chambers and to calculate VOC emission factors. The practice also specifies scenarios for typical school classrooms and offices that are used to estimate concentrations of the measured VOCs in buildings. The standard practice evaluates the acceptability of the estimated concentrations relative to Chronic Reference Exposure Level (CREL) guidelines for chronic, noncancer exposures of the general population to airborne toxicants. CRELs are developed by the California Office of Environmental Health Hazard Assessment and are air concentrations that would pose no significant health risks to individuals, including sensitive subpopulations, indefinitely exposed to these levels. CRELs are based solely on health considerations using the best available data in the scientific literature.

FloorScore Certification Program Introduced

In May 2005, the FloorScore Certification program was introduced. The program was developed by the Resilient Floor Covering Institute in conjunction with Scientific Certification Systems (SCS) and it tests and certifies hard surface flooring products for compliance with IAQ requirements developed and adopted in California. SCS is an internationally recognized third-party evaluation, testing, and certification organization. A flooring product that bears the FloorScore seal has been independently certified by SCS to comply with the VOC emissions criteria of the California Section 01350 program.

The FloorScore program is a voluntary program which complies with the IAQ performance requirements for low emitting building products as independently established by SCS's environmental certification program standard SCS-EC-10-2004. As a third party certification firm, SCS audits and determines whether products qualify for the FloorScore seal by meeting the requirements of SCS-EC-10-2004. Under this program, SCS:

1. Reviews all VOC emissions test reports generated by independent testing laboratories;

2. Determines whether the test results meet the California Section 01350 requirements for listed VOCs; and
3. Conducts periodic manufacturing plant inspections to review product formulas, processing, and quality control to ensure the continuing integrity of the FloorScore seal.

By basing the FloorScore program on publicly available documents, the program not only has specific and uniform requirements but also provides transparency which is often lacking with other VOC emissions testing programs.

Prior to introduction of the FloorScore program, there were no emissions testing programs focusing exclusively on hard surface flooring—an integral part of any building. In initiating an extensive emissions testing program of flooring materials and subsequently introducing FloorScore, the resilient flooring industry has gone far beyond any regulatory requirements in offering a voluntary certification program that allows specifiers, government agencies, and building owners to select hard surface flooring materials that meet specific emissions criteria.

FloorScore is a voluntary program, open to both members of RFCI and to other manufacturers for the certification of hard surface flooring and associated products with respect to their emissions of VOCs. The program covers a broad range of hard surface flooring materials, including linoleum, vinyl, rubber, cork, laminate, wood, and ceramic flooring materials.

Conclusions

The development of the FloorScore Certification program involved a large financial commitment and several years of testing, reformulating products and retesting, as well as studying the most current requirements for VOC emissions testing. The final objective was to develop a program to meet the needs of building owners, specifiers, regulatory agencies, sustainability standards bodies, and the scientific community. Since the FloorScore program was announced, over 200 hard surface flooring products have been certified under the program. FloorScore is now referenced in many environmental programs, including the U.S. Green Building Council's LEED rating system, the Green Building Initiative's Green Globes rating system, Collaborative for High Performance Schools (CHPS), Green Guide for Health Care, and EPA's Tools for Schools program. Architects, designers, specifiers, and building owners can help improve overall IAQ if they use hard surface flooring products certified under the FloorScore program. FloorScore cannot guarantee good health, but it does affirm that a flooring product has been independently verified to meet recognized performance criteria for listed VOCs under the California Section 01350 program.

References

[1] United States Environmental Protection Agency, Office of Toxic Substances, Carpet Policy Dialogue Compendium Report, September 27, 1991 (EPA/560/2–91–002, U. S. Dept. of Commerce, National Technical Information Center, Springfield, VA-703 487-4600).

[2] Swedish National Flooring Trade Association (GBR) and the Swedish National Testing and Research Institute (SP), Trade Standard: Measurement of Chemical Emission from Flooring Materials, Stockholm 1992-09-03 (GBR, Swedish National Flooring Trade Association, P.O. Box 4604, S11691, Stockholm, Sweden-46 8 644 0905).

[3] Indoor Air Bulletin, Vol. 3, No.10, Lars Molhave responds to "TVOC: Is It Dead?" (Hal Levin, Building Ecology Research Group, 2548 Empire Grade, Santa Cruz, CA 95060, 831-425-3946.

[4] Indoor Environment Review, Nov. 1996, "TVOC Measurement Ditched As Reliable IAQ Tool," IAQ Publications Inc., 7920 Norfolk Avenue, Suite 900, Bethesda, MD 20814 301-913-0115.

[5] California EPA Integrated Waste Management Board, Building Material Emissions Study, Nov. 2003, Integrated Waste Management Board, Public Affairs Office, Publications Clearing House (MS-6), 1001 I Street, P.O. Box 4025, Sacramento, CA 95812-4025, 916 341-6306 www.ciwmb.ca.gov/Publications/)

[6] Washington State Ventilation & Indoor Air Quality Code, Chapter 4, Indoor Air Quality, 1988, Washington Association of Building Oficials, 200 Union Ave, SE, Suite 200, P.O. Box 7310, Olympia, WA 98507-7310 www.halcyon.com/wabo

[7] United States Environmental Protection Agency, Office of Air and Radiation, "Healthy Buildings,

Healthy People—A Vision for the 21st Century," March 2000. (http://www.epa.gov/iaq)
[8] California Collaborative for High Performance Schools (CHPS) Best Practices Manual (www.chps.net)
[9] Scientific Certification Systems, SCS-EC10-2004 "Environmental Certification Program—Indoor Air Quality Performance," 2004 (www.scscertified.com)
[10] California Department of Health Services, Division of Environmental and Occupational Disease Control, Environmental Health Laboratory Branch, Indoor Air Quality Section, "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers," July 15, 2004, (http://www.dhs.ca.gov/ps/deodc/ehlb/iaq/VOCS/LORS/Section01350).

Journal of ASTM International, Vol. 5, No. 1
Paper ID JAI101078
Available online at www.astm.org

Barbara C. Lippiatt[1]

Evaluating Sustainability Using Standard Approaches: The BEES Tool

ABSTRACT: In support of the ASTM International, Symposium on Common Ground, Consensus Building and Continual Improvement, this paper describes the BEES (Building for Environmental and Economic Sustainability) software that integrates standard approaches for selecting cost-effective, environmentally-preferable building products. Version 4.0 of the Windows-based decision support software, aimed at designers, builders, and product manufacturers, includes actual environmental and economic performance data for over 230 building products across a range of functional applications. BEES measures the environmental performance of building products using the environmental life-cycle assessment approach specified in International Organization for Standardization (ISO) 14040 standards. All stages in the life of a product are analyzed: raw material acquisition, manufacture, transportation, installation, use, and waste management. Economic performance is measured using the ASTM International standard life-cycle cost method (E 917), which covers the costs of initial investment, replacement, operation, maintenance and repair, and disposal. Environmental and economic performance are combined into an overall performance measure using the ASTM standard for Multiattribute Decision Analysis (E 1765). For the entire BEES analysis, building products are defined and classified based on the ASTM standard classification for building elements known as UNIFORMAT II (E 1557).

KEYWORDS: building products, economic performance, environmental performance, green buildings, life cycle assessment, life-cycle costing, multiattribute decision analysis, sustainable development

Introduction

Selecting building products based on minimum life-cycle economic impacts is relatively straightforward. Products are bought and sold in the marketplace, which established the first cost; and sound analytical procedures to quantify life-cycle cost have been developed and employed for over 20 years. In addition to initial cost, future costs that contribute to life-cycle cost include the cost of energy, operation and maintenance, labor and supplies, replacement parts, and eventually the cost of decommissioning or recycling the system.

But how do we include life-cycle environmental impacts in our purchase decisions? Environmental impacts, such as global warming, indoor air quality, water pollution, and resource depletion, are for the most part economic externalities. That is, their costs are not reflected in the market prices of the products that generated the impacts. Moreover, even if there were a mandate today to include environmental "costs" in market prices, it would be nearly impossible to do so due to difficulties in assessing these impacts in classical economic terms. How do you put a price on clean air and clean water? What, ultimately, is the price of human life, and how do we value the avoidance of its loss? Economists have debated these questions for decades, and a consensus does not appear imminent.

While environmental performance cannot be measured on a monetary scale, it can be quantified using the evolving, multi-disciplinary approach known as environmental life-cycle assessment (LCA). All stages in the life of a product are analyzed: raw material acquisition, manufacture, transportation, installation, use, and recycling and waste management. The National Institute of Standards and Technology BEES (Building for Environmental and Economic Sustainability) tool [1] applies an LCA approach to measure the environmental performance of building products, following guidance in the International Organization for Standardization (ISO) 14040 series of standards for LCA [2]. BEES separately measures economic performance using the ASTM International standard life-cycle cost (LCC) approach [3]. These two per-

Manuscript received March 16, 2007; accepted for publication October 18, 2007; published online January 2008.
[1] National Institute of Standards and Technology, Gaithersburg, MD 20899-8603.

formance measures are then synthesized into an overall performance measure using the ASTM standard for Multiattribute Decision Analysis [4]. For the entire BEES analysis, building products are defined and classified based on UNIFORMAT II, the ASTM standard classification for building elements [5].

Measuring Environmental Performance

Environmental life-cycle assessment is a "cradle-to-grave" systems approach for measuring environmental performance. It is based on the belief that all stages in the life of a product generate environmental impacts and must therefore be analyzed. The stages include:

- Raw materials acquisition
- Product manufacture
- Transportation
- Installation
- Operation and maintenance
- Recycling and waste managementAn analysis that excludes any of these stages is limited because it ignores the full range of upstream and downstream impacts of stage-specific processes.

The strength of environmental life-cycle assessment is its comprehensive, multi-dimensional scope. Many sustainable building claims and strategies are now based on a single life-cycle stage or a single environmental impact. A product is claimed to be green simply because it has recycled content, or accused of not being green because it emits volatile organic compounds (VOCs) during its installation and use. These single-attribute claims may be misleading because they ignore the possibility that other life-cycle stages, or other environmental impacts, may yield offsetting effects. For example, the recycled content product may have a high embodied energy content, leading to resource depletion, global warming, and acid rain impacts during the raw materials acquisition, manufacturing, and transportation life-cycle stages. LCA thus broadens the environmental discussion by accounting for shifts of environmental problems from one life-cycle stage to another, or one environmental medium (land, air, or water) to another. The benefit of the LCA approach is in implementing a trade-off analysis to achieve a genuine reduction in overall environmental impact, rather than a simple shift of impact.

The general LCA methodology involves four steps. The goal and scope definition step spells out the purpose of the study and its breadth and depth. The inventory analysis step identifies and quantifies the environmental inputs and outputs associated with a product over its entire life cycle. Environmental inputs include water, energy, land, and other resources; outputs include releases to air, land, and water. However, it is not these inputs and outputs, or inventory flows, that are of primary interest. We are more interested in their consequences, or impacts on the environment. Thus, the next LCA step, impact assessment, characterizes these inventory flows in relation to a set of environmental impacts. For example, impact assessment might relate carbon dioxide emissions, a flow, to global warming, an impact. Finally, the interpretation step combines the environmental impacts in accordance with the goals of the LCA study.

Goal and Scope Definition

The goal of the BEES LCA is to generate relative environmental performance scores for building product alternatives sold in the United States. These scores are combined with economic performance scores to help the building community select environmentally and economically balanced building products.

The scoping phase of any LCA involves defining the boundaries of the product system under study. The manufacture of any product involves a number of unit processes (e.g., ethylene production for input to the manufacture of the styrene-butadiene bonding agent for stucco walls). Each unit process involves many inventory flows, some of which themselves involve other, subsidiary unit processes.

The first product system boundary determines which unit processes are included in the LCA. In the BEES approach, the boundary-setting rule consists of a set of three decision criteria. For each candidate unit process, mass and energy contributions to the product system are the primary decision criteria. In some cases, cost contribution is used as a third criterion [6]. Together, these criteria provide a robust screening process.

The second product system boundary determines which inventory flows are tracked for in-bounds unit processes. Quantification of all inventory flows is not practical for the following reasons:

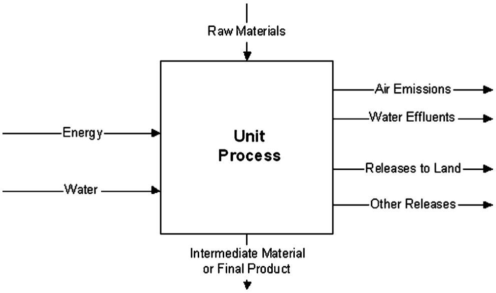


FIG. 1—*BEES inventory data categories.*

- An ever-expanding number of inventory flows can be tracked. For instance, including the U.S. Environmental Protection Agency's Toxic Release Inventory (TRI) data would result in tracking approximately 200 inventory flows arising from polypropylene production alone. Similarly, including radionucleide emissions generated from electricity production would result in tracking more than 150 flows. Managing such large inventory flow lists adds to the complexity, and thus the cost, of carrying out and interpreting the LCA.
- Attention should be given in the inventory analysis step to collecting data that will be useful in the next LCA step, impact assessment. By restricting the inventory data collection to the flows actually needed in the subsequent impact assessment, a more focused, higher quality LCA can be carried out.

Therefore, in the BEES model, a focused, cost-effective set of inventory flows is tracked, reflecting flows that will actually be needed in the subsequent impact assessment step.

Defining the unit of comparison is another important task in the goal and scoping phase of LCA. The basis for all units of comparison is the functional unit, defined so that the products compared are true substitutes for one another. In the BEES model, the functional unit for most building products is 0.09 m^2 (1 ft^2) of product service for 50 years [7]. Therefore, for example, the functional unit for the BEES roof covering alternatives is covering 0.09 m^2 (1 ft^2) of roof surface for 50 years. The functional unit provides the critical reference point to which all inventory flows are scaled.

Scoping also involves setting data requirements. Data requirements for the BEES study include:

- Geographic coverage: The data are U.S. average data.
- Time period: The data are a combination of information collected specifically for BEES within the past 10 years, and from the well-known Ecobalance LCA database created in 1990 [8]. Most of the Ecobalance data are updated annually. No data older than 1990 are used.
- Technology: When possible, the most representative technology is studied. Where data for the most representative technology are not available, an aggregated result is used based on the U.S. average technology for that industry.

Inventory Analysis

Inventory analysis entails quantifying the inventory flows for a product system. Inventory flows include inputs of water, energy, and raw materials, and releases to air, land, and water. Data categories are used to group inventory flows in LCAs. For example, in the BEES model, flows such as aldehydes, ammonia, and sulfur oxides are grouped under the air emissions data category. Figure 1 shows the categories under which data are grouped in the BEES system. For each product included in BEES, up to 400 inventory flow items are tracked.

A number of approaches may be used to collect inventory data for LCAs [9]. These range from:

- Unit process- and facility-specific: Data collected from a particular process within a given facility that are not combined in any way.
- Composite: Data collected from the same process combined across locations.
- Aggregated: Data collected combining more than one process.

- Industry-average: Data derived from a representative sample of locations believed to statistically describe the typical process across technologies.
- Generic: Data without known representation, but that are qualitatively descriptive of a process.

Since the goal of the BEES LCA is to generate U.S. industry-average results, generic product data are collected primarily using the industry-average approach. Manufacturer-specific product data are collected primarily using the unit process- and facility-specific approaches, then aggregated to preserve manufacturer confidentiality. Data collection is done under contract with Environmental Strategies and Solutions (ESS) and PricewaterhouseCoopers/Ecobalance, using the Ecobalance LCA database, which covers more than 6000 industrial processes gathered from actual site and literature searches from more than 15 countries. Where necessary, the data are adjusted to be representative of U.S. operations and conditions. Approximately 90 % of the data come directly from industry sources, with about 10 % from generic literature and published reports. The generic data include inventory flows for electricity production from the average U.S. grid, and for selected raw material mining operations (e.g., limestone, sand, and clay mining operations). In addition, ESS and Ecobalance gathered additional LCA data to fill data gaps for the BEES products. Assumptions regarding the unit processes for each building product are verified through experts in the appropriate industry to assure the data are correctly incorporated in BEES.

Impact Assessment

The impact assessment step of LCA quantifies the potential contribution of a product's inventory flows to a range of environmental impacts. BEES takes primarily an Environmental Problems approach to impact assessment, as developed within the Society for Environmental Toxicology and Chemistry (SETAC). It involves a two-step process [10]:

1. Classification of inventory flows that contribute to specific environmental impacts. For example, greenhouse gases, such as carbon dioxide, methane, and nitrous oxide, are classified as contributing to global warming.
2. Characterization of the potential contribution of each classified inventory flow to the corresponding environmental impact. This results in a set of indices, one for each impact, that is obtained by weighting each classified inventory flow by its relative contribution to the impact. For instance, the Global Warming Potential index is derived by expressing each contributing inventory flow in terms of its equivalent amount of carbon dioxide.

The BEES model uses this Environmental Problems approach where possible because it enjoys some general consensus among LCA practitioners and scientists [11]. The U.S. EPA Office of Research and Development has developed TRACI (Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts), a set of state-of-the-art, peer-reviewed U.S. life-cycle impact assessment methods that has been adopted in BEES 4.0 [12]. Ten of the eleven TRACI impacts follow the Environmental Problems approach:

- Global warming potential
- Acidification potential
- Eutrophication potential (unwanted addition of mineral nutrients to the soil or water, which can lead to undesirable ecosystem shifts)
- Fossil fuel depletion
- Habitat alteration
- Criteria air pollutants
- Smog
- Ecological toxicity
- Human health toxicity
- Ozone depletion

Water Intake is assessed in TRACI, and adopted in BEES 4.0, using the Direct Use of Inventories Approach, meaning that the life-cycle inventory results are used as-is in the final interpretation step. BEES also assesses Indoor Air Quality, an impact not included in TRACI because it is unique to the building industry. Indoor Air Quality is also assessed using the Direct Use of Inventories approach, for a total of twelve impacts for most BEES products.

Interpretation

At the LCA interpretation step, the impact assessment results are combined. Few products are likely to dominate their competition in all impact categories. One product may outperform the competition in terms of fossil fuel depletion and solid waste, but may fall short relative to global warming and acidification, and fall somewhere in the middle on the basis of indoor air quality and eutrophication. To compare the overall environmental performance of competing products, the performance measures for all impact categories may be synthesized. (Note that in BEES, synthesis of impact measures is optional.)

Synthesizing the impact category performance measures involves combining "apples and oranges." Global warming potential is expressed in carbon dioxide equivalents, acidification in hydrogen ion equivalents, eutrophication in nitrogen equivalents, and so on. How can these diverse measures of impact category performance be combined into a meaningful measure of overall environmental performance? The most appropriate technique is Multiattribute Decision Analysis (MADA). MADA problems are characterized by tradeoffs, as is the case with the BEES impact assessment results. The BEES system follows the ASTM standard for conducting MADA evaluations of building-related investments [13].

MADA first places all impact categories on the same scale by normalizing them. Within BEES, each impact category is normalized using U.S. EPA data corresponding to its TRACI set of impact assessment methods. These data estimate the per capita annual contribution to each impact in the United States, and are used to place each product-specific impact category performance measure in the context of all U.S. activity contributing to that impact. Normalization is accomplished by dividing BEES product-specific impact values by the fixed U.S.-scale impact values, and yields a product's percentage shares of the U.S. values. For example, suppose Product XYZ's life-cycle global warming contribution is 1 300 000 grams of carbon dioxide equivalents and U.S. contributions are 26 000 000 grams of carbon dioxide equivalents/year/capita. Through normalization, Product XYZ's percentage share of U.S. contributions is derived: 0.05 % (=1 300 000/26 000 000). By similarly normalizing all product-specific impact values, all performance measures are translated to the same scale, allowing comparison across impacts.

Normalized impact scores may also be compared across building elements if they are first scaled to reflect the product quantities to be used in the building under analysis over the same time period. For example, consider the global warming scores for roof coverings and chairs. If these scores are each first multiplied by the quantity of their functional units to be used in a particular building (roof area to be covered and seating requirements, respectively), they may then be compared. Comparing across elements can provide insights into which buildings elements lead to the larger environmental impacts and thus warrant the most attention.

MADA computes a weighted average environmental performance score after weighting each impact category by its relative importance to overall environmental performance. In the BEES software, the set of importance weights is selected by the user. Several derived, alternative weight sets are provided as guidance, and may be used either directly or as a starting point for developing user-defined weights. The alternative weight sets are based on an EPA Science Advisory Board study, a Harvard University study, and a set of equal weights, representing a spectrum of ways in which people value various aspects of the environment.

Measuring Economic Versus Environmental Performance

Measuring the economic performance of building products is more straightforward than measuring environmental performance. Published economic performance data is readily available, and there are well-established ASTM standard methods for conducting economic performance evaluations. First, cost data are collected from the latest edition of the R.S. Means annual publication, *Building Construction Cost Data*, and future cost data are based on the latest data published by Whitestone Research in *The Whitestone Building Maintenance and Repair Cost Reference*, supplemented by industry interviews. The most appropriate method for measuring the economic performance of building products is the life-cycle cost (LCC) method. (See Chapter 13 for full coverage of LCC.) BEES follows the ASTM standard method for life-cycle costing of building-related investments [14].

It is important to distinguish between the time periods used to measure environmental performance and economic performance, which are different. Recall that in environmental LCA, the time period begins with raw material acquisition and ends with product end-of-life. Economic performance, on the other hand,

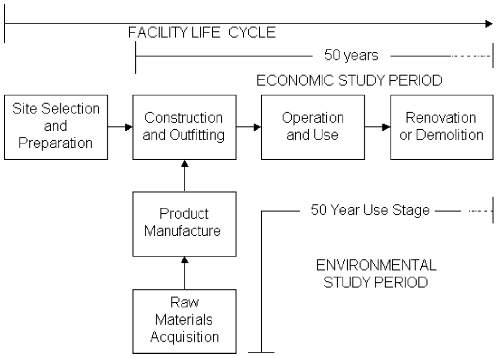


FIG. 2—*BEES study periods for measuring building product environmental and economic performance.*

is evaluated over a fixed period (known as the study period) that begins with the purchase and installation of the product, and ends at some point in the future that does not necessarily correspond with product end-of-life.

Economic performance is evaluated beginning at product purchase and installation because this is when out-of-pocket costs begin to be incurred, and investment decisions are made based on out-of-pocket costs. The study period ends at a fixed date in the future. For a private investor, its length is set at the period of product or facility ownership. For society as a whole, the study period length is often set at the useful life of the longest-lived product alternative. However, when all alternatives have very long lives (e.g., more than 50 years), a shorter study period may be selected for three reasons:

- Technological obsolescence becomes an issue.
- Data become too uncertain.
- The further in the future, the less important the costs.

In the BEES model, economic performance is measured over a 50-year study period, as shown in Fig. 2. This period is selected to reflect a reasonable period of time over which to evaluate economic performance for society as a whole. The same 50-year period is used to evaluate all products, even if they have different useful lives. This is one of the strengths of the LCC method. It adjusts for the fact that different products have different useful lives when evaluating them over the same study period.

For consistency, the BEES model evaluates the use stage of environmental performance over the same 50-year study period. Product replacements over this 50-year period are accounted for in the environmental performance score, and end-of-life solid waste is prorated to year 50 for products with partial lives remaining after the 50-year period.

The LCC method totals all relevant costs associated with a product over the study period. Alternative products for the same function, such as floor covering, can then be compared on the basis of their LCCs to determine which is the least costly means of providing that function over the study period. Categories of cost typically include costs for purchase, installation, maintenance, repair, and replacement. A negative cost item is the residual value. The residual value is the product value remaining at the end of the study period. In the BEES model, the residual value is computed by prorating the purchase and installation cost over the product life remaining beyond the 50-year period [15].

The LCC method accounts for the time value of money by using a discount rate to convert all future costs to their equivalent present value. Future costs must be expressed in terms consistent with the discount rate used. There are two approaches. First, a real discount rate may be used with constant-dollar costs (e.g., Year 2002). Real discount rates reflect the portion of the time value of money attributable to the real earning power of money over time, and not to general price inflation. Even if all future costs are expressed in constant Year 2002 dollars, they must be discounted to reflect this portion of the time value of money. Second, a market discount rate may be used with current-dollar amounts (e.g., actual future prices). Market discount rates reflect the time value of money stemming from both inflation and the real earning power of money over time. When applied properly, both approaches yield the same LCC results. The current version of BEES computes LCCs using constant Year 2002 dollars and a real discount rate. As a default, it uses a

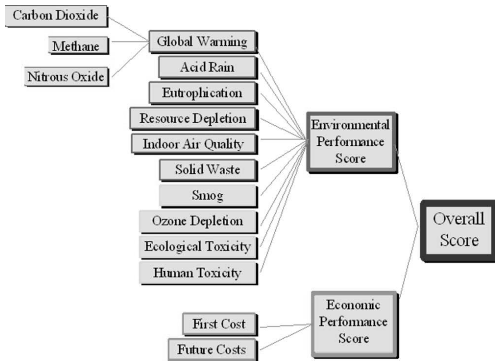


FIG. 3—*Deriving the BEES overall performance score.*

real rate of 3.9 %, the 2002 rate mandated by the U.S. Office of Management and Budget (OMB) for most federal projects [16].

Overall Performance: Economic and Environmental

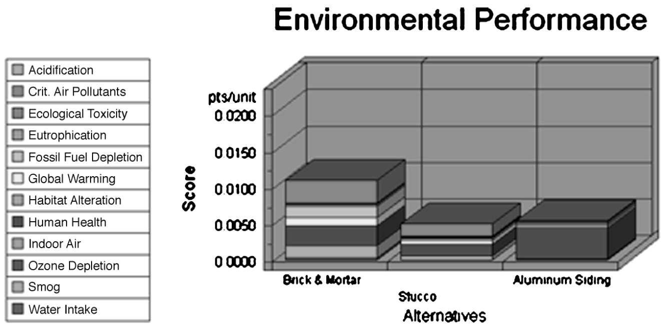
The BEES overall performance score combines the environmental and economic results into a single score, as illustrated in Fig. 3. Before combining the two, each is placed on a common scale by dividing by the sum of corresponding scores across all alternatives under analysis. In effect, then, each performance score is rescaled in terms of its share of all scores, and is placed on the same relative scale from 0 to 100. Then the environmental and economic performance scores are combined into an overall score by weighting environmental and economic performance by their relative importance and taking a weighted average. The BEES user specifies the relative importance weights used to combine environmental and economic performance scores and may test the sensitivity of the overall scores to different sets of relative importance weights. Figures 4–6 show three BEES summary graphs illustrating how BEES reports environmental, economic, and overall performance, respectively, based on user-defined importance weights.

Limitations

Properly interpreting the BEES scores requires placing them in perspective. There are inherent limits to applying U.S. average LCA and LCC results and in comparing building products outside the design context.

The BEES LCA and LCC approaches produce U.S. average performance results for generic and manufacturer-specific product alternatives. The BEES results do not apply to products manufactured in other countries where manufacturing and agricultural practices, fuel mixes, environmental regulations, transportation distances, and labor and material markets may differ [17]. Furthermore, all products in a generic product group, such as vinyl composition tile floor covering, are not created equal. Product composition, manufacturing methods, fuel mixes, transportation practices, useful lives, and cost can all vary for individual products in a generic product group. The BEES results for the generic product group do not necessarily represent the performance of an individual product.

The BEES LCAs use selected inventory flows converted to selected local, regional, and global environmental impacts to assess environmental performance. Those inventory flows that currently do not have scientifically proven or quantifiable impacts on the environment are excluded. Examples are mineral extraction and wood harvesting, which are qualitatively thought to lead to loss of habitat and an accompanying loss of biodiversity, but whose impacts may not have been quantified. If the BEES user has important knowledge about these or other potential environmental impacts, this information should be brought into the interpretation of the BEES results.



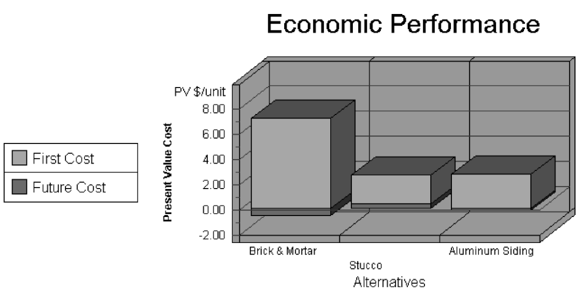
Note: Lower values are better

Category	Brick	Stucco	Aluminum
Acidification--9%	0.0000	0.0000	0.0000
Crit. Air Pollutants--8%	0.0031	0.0018	0.0001
Ecolog. Toxicity--8%	0.0001	0.0001	0.0002
Eutrophication--9%	0.0004	0.0001	0.0001
Fossil Fuel Depl.--9%	0.0015	0.0003	0.0002
Global Warming--9%	0.0011	0.0006	0.0003
Habitat Alteration--8%	0.0000	0.0000	0.0000
Human Health--8%	0.0028	0.0015	0.0043
Indoor Air--8%	0.0000	0.0000	0.0000
Ozone Depletion--8%	0.0000	0.0000	0.0000
Smog--8%	0.0017	0.0006	0.0002
Water Intake--8%	0.0003	0.0001	0.0000
Sum	0.0110	0.0051	0.0054

FIG. 4—*Viewing BEES environmental performance results.*

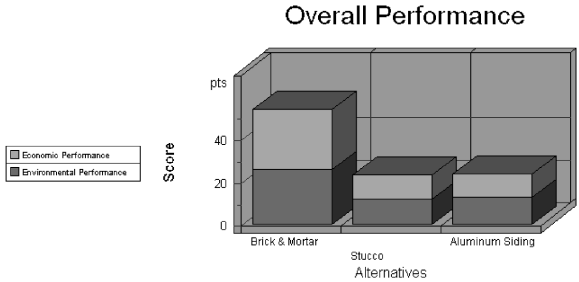
During the interpretation step of the BEES LCA, environmental impacts are optionally combined into a single environmental performance score using relative importance weights. These weights necessarily incorporate values and subjectivity. BEES users should routinely test the effects on the environmental performance scores of changes in the set of importance weights.

The BEES overall scores do not represent absolute environmental performance. Rather, they represent proportional differences in performance, or relative performance, among competing alternatives. Consequently, the overall performance score for a given product alternative can change if one or more competing



Category	Brick	Stucco	Aluminum
First Cost	7.13	2.27	2.71
Future Cost-- 3.9%	-0.53	0.36	-0.15
Sum	6.60	2.63	2.56

FIG. 5—*Viewing BEES economic performance results.*



Note: Lower values are better

Category	Brick	Stucco	Aluminum
Economic Perform.--50%	28.0	11.2	10.9
Environ. Perform.--50%	25.6	11.9	12.6
Sum	53.6	23.1	23.5

FIG. 6—*Viewing BEES overall performance results.*

alternatives are added to or removed from the set of alternatives under consideration. In rare instances, rank reversal, or a reordering of scores, is possible. Finally, since they are relative performance scores, no conclusions may be drawn by comparing overall scores across building elements. That is, if exterior wall finish Product A has an overall performance score of 30, and roof covering Product D has an overall performance score of 20, Product D does not necessarily perform better than Product A (keeping in mind that lower performance scores are better). This limitation does not apply to comparing environmental performance scores across building elements, as noted above.

There are inherent limits to comparing product alternatives without reference to the whole building design context. First, this approach may overlook important environmental and cost interactions among building elements. For example, the useful life of one building element (e.g., floor coverings), which influences both its environmental and economic performance scores, may depend on the selection of related building elements (e.g., subflooring). There is no substitute for good building design.

Environmental and economic performance are but two attributes of building product performance. The BEES model assumes that competing product alternatives all meet minimum technical performance requirements [18]. However, there may be significant differences in technical performance, such as acoustical performance, fire performance, or aesthetics, which may outweigh environmental and economic considerations.

Conclusion

Applying the BEES approach leads to several general conclusions. First, environmental claims based on single impacts, such as recycled content alone, should be viewed with skepticism. These claims do not account for the fact that one impact may have been improved at the expense of others. Second, measures must always be quantified on a functional unit basis as they are in BEES, so that the products being compared are true substitutes for one another. One roof covering product may be environmentally superior to another on a pound-for-pound basis, but if that product requires twice the mass as the other to cover one square foot of roof, the results may reverse. Third, a product may contain a negative-impact constituent, but if that constituent is a small portion of an otherwise relatively benign product, its significance decreases dramatically. Finally, a short-lived, low-first-cost product is often not the cost-effective alternative. A higher first cost may be justified many times over for a durable, maintenance-free product. In sum, the answers lie in the trade-offs.

References

[1] BEES is developed by the National Institute of Standards and Technology(NIST) Building and Fire

Research Laboratory with support from the U.S. EPA Environmentally Preferable Purchasing Program. The current version, BEES 4.0, aimed at designers, builders, and product manufacturers, includes even actual environmental and economic performance data for 230 building products spread across a range of building applications. The BEES software and manual may be downloaded free of charge from www.bfrl.nist.gov/oae/software/bees.html

[2] International Organization for Standardization, "Environmental Management—Life-Cycle Assessment—Principles and Framework," International Standard 14040, 1997; ISO "Environmental Management—Life-Cycle Assessment—Goal and Scope Definition and Inventory Analysis," International Standard 14041, 1998; and ISO "Environmental Management—Life-Cycle Assessment—Life Cycle Impact Assessment," International Standard 14042, 2000.

[3] ASTM Standard E 917-99, "Standard Practice for Measuring Life-Cycle Costs of Buildings and Building Systems," *Annual Book of ASTM Standards*, ASTM International, West Conshohocken, PA, 1999.

[4] ASTM Standard E 1765-98, "Standard Practice for Applying the Analytic Hierarchy Process to Multiattribute Decision Analysis of Investments Related to Buildings and Building Systems," *Annual Book of ASTM Standards*, ASTM International, West Conshohocken, PA, 1998.

[5] ASTM Standard E 1557-97, "Standard Classification for Building Elements and Related Sitework—UNIFORMAT II," *Annual Book of ASTM Standards*, ASTM International, West Conshohocken, PA, September 1997.

[6] While a large cost contribution does not directly indicate a significant environmental impact, it may indicate scarce natural resources or numerous subsidiary unit processes potentially involving high energy consumption.

[7] All product alternatives are assumed to meet minimum technical performance requirements (e.g., acoustic and fire performance).

[8] Ecobalance, Inc., "DEAM™ 3.0: Data for Environmental Analysis and Management," Bethesda, MD, 1999.

[9] U.S. Environmental Protection Agency, Office of Research and Development, "Life Cycle Assessment: Inventory Guidelines and Principles," EPA/600/R-92/245, February 1993.

[10] SETAC-Europe, *Life Cycle Assessment*, B. DeSmet et al., Eds., 1992; SETAC, *A Conceptual Framework for Life Cycle Impact Assessment*, J. Fava et al., Eds., 1993; and SETAC, *Guidelines for Life Cycle Assessment: A Code of Practice*, F. Consoli et al., Eds., 1993.

[11] SETAC, *Life-Cycle Impact Assessment: The State-of-the-Art*, J. Owens et al., Eds., 1997.

[12] U.S. Environmental Protection Agency, *Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI): User's Guide and System Documentation*, EPA/600/R-02/052, U.S. EPA Office of Research and Development, Cincinnati, OH, August 2002.

[13] ASTM Standard E 1765-98, "Standard Practice for Applying the Analytic Hierarchy Process to Multiattribute Decision Analysis of Investments Related to Buildings and Building Systems," *Annual Book of ASTM Standards*, ASTM International, West Conshohocken, PA, 1998.

[14] ASTM Standard E 917-99, "Standard Practice for Measuring Life-Cycle Costs of Buildings and Building Systems," *Annual Book of ASTM Standards*, ASTM International, West Conshohocken, PA, 1999. Note that the Building Life-Cycle Cost (BLCC) software discussed in the next chapter also follows this ASTM standard method in conducting its life-cycle costing evaluations.

[15] For example, a product with a 40-year life that costs $10 per 0.09 square meter ($10 per square foot) to install would have a residual value of $7.50 in year 50, considering replacement in year 40.

[16] Office of Management and Budget (OMB) Circular A-94, "Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs," Washington, DC, October 27, 1992 and OMB Circular A-94, Appendix A-94, 2002.

[17] BEES does apply to products manufactured in other countries and sold in the United States. These results, however, do not apply to those same products as sold in other countries because transport to the United States is built into their BEES life cycle inventory data.

[18] Environmental and economic performance results for wall insulation, roof coverings, and concrete beams and columns do consider technical performance differences. For wall insulation and roof coverings, BEES accounts for differential heating and cooling energy use. For concrete beams and columns, BEES accounts for different compressive strengths.

Journal of ASTM International, Vol. 4, No. 7
Paper ID JAI101101
Available online at www.astm.org

Wolfram Trinius[1,2] *and Christer Sjöström*[2]

Sustainability in Building Construction—International Standards in Progress

ABSTRACT: The development of ISO 15392 on general principles of sustainability in building construction took more time than expected. The most significant reason for this was the need to identify a common basis for the conceptual content of the document. With this basis now being identified, the work has taken up momentum and the general principles document presents principles to be considered when addressing the thematic field of sustainable development in relation to building and civil engineering. A key problem to be tackled in international standardization is finding the balance between the necessary level of detail to actually provide something to the user of the standard, and at the same time not to be too specific in order to allow different nations and their specific perspectives to still agree to the standard. While the challenge of sustainable development is global, the strategies for addressing sustainability in building construction are local and differ in context and content from region to region. Such strategies will reflect the context not only in the building environment, but also very much the social environment. This social environment includes cultural issues, legislation and regulation, as well as the needs and concerns of all the users and interested parties involved. Applying the concept of sustainability to specific buildings or other construction works includes a holistic approach, bringing together the global concerns and goals of sustainable development and the demands and requirements in terms of product functionality, efficiency, and economy. Different target audiences will have a different perspective on these challenges and the preferred solutions. The standards must hence put the topic onto a common playing field, still allowing different perspectives to be applied and priorities to be set, as well as recognizing that many aspects of sustainable development lie without the possible content of international technical standardization. ISO 15392 is related to and set into the context of other international standards and widely applied concepts, such as the performance-based building concept and the ISO 15686 series. This paper illustrates the set of related international standards and discusses the modular application. We want to discuss key factors needing consideration in order to bring the set of standards to successful application.

KEYWORDS: sustainability in building construction, performance-based building, modularity

Abbreviations

PBB Performance-Based Building
SLP Service Life Planning
EPD Environmental Product Declaration

Introduction

The international standardization work on the document ISO 15392 Sustainability in Building Construction—General Principles [1] is carried out under ISO TC59/SC17 "Sustainability in Building Construction." This subcommittee is the first ISO committee that expressly carries the wording *sustainability* in its title. However, the work of SC17 is strongly related to other ISO committees' work, namely TC59/SC14 on Design Life and TC207 on Environmental Management.

NOTE: Much of this international work is reflected and developed to a European context by the European Committee for Standardization (CEN) through the work of:

- *CEN TC350 on Sustainability of Construction Works, and*
- *CEN TC351 on Construction Products—Release of Regulated Dangerous Substances.*

While the established ISO standards in the ISO 9000 and the ISO 14000 series have a management approach focusing on organizations and processes, TC59/SC17 as well as SC14 focus on construction

Manuscript received March 6, 2007; accepted for publication June 26, 2007; published online August 2007.
[1] Centre for Built Environment, University of Gävle, 80176 Gavle, Sweden.
[2] Professor, Ingenieurbüro Trinius, Dorotheenstr. 21, 22301 Hamburg, Germany.

works, meaning buildings or other civil engineering works. As opposed to technical standards that directly address the products, these standards from ISO TC59 are procedural standards, not technical.

The scope of SC17 encompasses the three spheres of sustainability (economic, environmental, and social aspects of sustainability) seen over the complete life cycle of a building or civil engineering works.

Sustainability—A Global Challenge

The concept of *sustainability* was established in the Brundtland Report [2], as well as the various local Agenda 21 activities and discussions on restrictive emission protocols, both of which are political documents. With its Agenda 21 on sustainable construction [3], CIB has identified a sectorial interpretation of the Brundtland report and an in-depth and prospective analysis of the future directions of research and innovation in building and construction. The ISO standards aim to implement the concept of sustainability and to bring consideration of sustainability aspects to an internationally established common ground, without being political. Consequently, international standards can harmonize the approaches that enable various stakeholders to communicate product-related sustainability information, obtained on a commonly agreed methodological basis. Meanwhile, the political agenda including target settings and identification of priorities needs to be performed by other organizations, whether governmental or nongovernmental.

The relevance to move the building and construction sector towards a better performance in terms of sustainability has been pointed out in numerous publications and is usually illustrated by figures stating that the sector roughly stands for 40 % of the global energy consumption and waste generation and 50 % of CO_2 emissions. The economic value of the building stock including infrastructure is often among the largest assets in national economies. As we tend to spend more than 90 % of our time in buildings or in transportation between buildings, it is easily understood that all three primary aspects of sustainability, economic, environmental and social aspects, are highly significant for consideration in the building and construction sector.

Sustainable Building—Local Strategies

The global relevance and the need for consideration of sustainability aspects relative to buildings directly translate into the need for regional and local strategies (see, e.g., Agenda 21 for Sustainable Construction in Developing Countries [4]) addressing the industrial sector, its products, and stakeholders. Due to the fact that buildings and infrastructure are an integrated part of our social lives, the interests of humans, both individually and collectively, need to be given attention, especially when quality of life issues are included in the discussion of sustainability. The inter-linkage with aspects such as cultural heritage, tradition, identity, and governance can only stress that one globally valid and detailed standard on sustainability cannot be successful. Quite the contrary, international standards on sustainability need to make allowance for specific considerations, values, priorities, etc., to be embedded in sustainability considerations. ISO 15392 [1] states in its *Introduction:*

> *While the challenge of sustainable development is global, the strategies for addressing sustainability in building construction are local and differ in context and content from region to region. These strategies will reflect the context not only in the built environment, but also in the social environment.*

Ultimately, the work of ISO/TC59/SC17 reflects this with the approach to harmonize the terminology related to sustainability in building construction, and to provide a framework document on general principles, which can set out the critical items needed to be considered. In the scope of the work, it is clarified that a building needs to be considered from a complete life cycle perspective, and that it needs to be seen in its context. This context lies at hand in not only the products and assembled systems applied in a building, but also in the local neighborhood and the built environment within which a building becomes functional. Ultimately, the building provides a function to its users and needs to fulfill performance requirements. The processes applied in order to obtain and to maintain the functional and performance aspects provided by the building require specific consideration. The requirements to be fulfilled by the building are understood as the reference point in terms of performance assessment of the building. As many different stakeholders have different, albeit legitimate, points of interest and, consequently, express different requirements of buildings (singularly or collectively), the ISO standard on general principles needs to be applicable to all of these different perspectives. Consequently, it cannot provide stringent guidance on details and it needs to recognize, and enable adaptation to, local and individual concerns.

ISO Standards

According to the ISO policy on standards [5], ISO standards shall:

- effectively respond to regulatory and market needs (in the global marketplace);
- not stifle innovation and technological development; and
- be performance-based as opposed to prescriptive.

Within the International Organization for Standardization (ISO), standards addressing sustainability in building construction and related items are primarily developed by:

- ISO/TC59/SC17 Sustainability in Building Construction
- ISO/TC59/SC14 Design Life.

Performance Concept

With the above quoted policy statement that ISO standards are to be performance-based rather than prescriptive, the standards must embrace the concept of performance-based building. This concept is based on the clear and unambiguous identification of verifiable performance requirements. A performance evaluation sets the performance that a building provides in relation to these requirements. The concept of service life planning, which is briefly described below, allows for the consideration of how the performance of the building develops over time. The steps in planning, from establishing design requirements through initial performance to long-term performance, or life cycle performance, are the accumulated content of these two concepts.

ISO 15686 Series

The ISO 15686 series contains standards on service life planning of constructed assets [6–15]. The series comprises a model for the determination of a reasonable expected service life for buildings and components, and it establishes a routine for the assessment of design alternatives. A design option is considered reasonable when it meets or exceeds performance requirements over time. These requirements need to be drawn up specifically for the specific project; they may originate from the clients brief, from regulation, or from organizational targets and they may reflect opportunities as well as limitations at hand in the actual project.

When relating assessments to established performance requirements (see Fig. 1), an evident link to the concept of performance-based building is established. Any stakeholder involved in the value chain or in the design process of the building, as well as regulators and building users, can express performance requirements. Identified requirements, both in relevance and in quality, will vary with the stakeholder and his/her perspective of interest. Consequently, when applying ISO 15686 standards, assessments and the discussion of a design option’s suitability will be reflecting the actual stakeholders demands embedded in other relevant requirements.

ISO 15392

Based on the understanding that there is no absolute measure indicating that a building is sustainable, sustainable development of buildings is said to provide the required performance with minimum adverse environmental impacts, while encouraging improvements in economic and social aspects. This involves both local, regional, and global scales as well as it relates to single products, functional components (assembled systems), services, and processes linked to the life cycle of a building.

The conceptual content of ISO 15392 is best explained by a direct quote from its introduction [1]:

> *Applying the concept of sustainability to specific buildings or other construction works includes an holistic approach, bringing together the global concerns and goals of sustainable development and the demands and requirements in terms of product functionality, efficiency and economy. Different target audiences will have a different perspective on the challenges and the preferred solutions.*

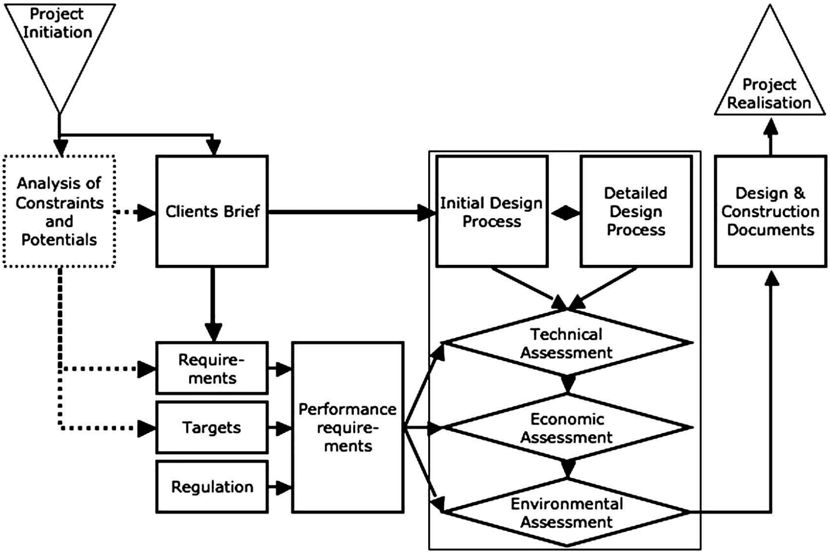


FIG. 1—*Technical, economic, and environmental assessment as part of the design process and on the basis of identified performance requirements, adapted from ISO 15686-6 [11].*

In relation to the provision and the application of information relative to sustainability aspects of buildings and other products of the building and construction sector, the general principles standard is intended to provide the common grounds on which other more thematically specific standards are developed. ISO 15392 states that:

> *It is important that an internationally recognized framework be established and that this framework allows for the establishment of a common basis for communication of information required. Interested parties, such as product manufacturers and designers will then be able to provide information according to this framework. Such information can then be communicated internationally and to a wide range of target audiences, extending from politicians and regulators to manufacturers, building owners and consumers.*
>
> *The recipients of information can elaborate and interpret information according to their own perspective, reflecting other aspects of decision-making, including fields of responsibility or constraints. These general principles do not provide a benchmark against which a claim of sustainability can be made.*

ISO Suite of Standards on Sustainability in Building Construction

ISO TC59 SC17 also works on the items "terminology," "sustainability indicators," "framework for methods of assessment of environmental performance of buildings," and "environmental declaration of building products." The latter two work items are restricting themselves primarily to the consideration of environmental aspects of sustainability. Consequently, they have a much stronger restriction in their scope than the general principles document. In the long run, if applicable, the intention must be to also develop standards that bring the other sustainability aspects to a comparable level, all in order to allow a balanced and holistic approach.

When applying any of the standards from SC17 or from the ISO 15686 series [6–15], it becomes rapidly clear that these benefit from an integrated or consequential application. See the examples below.

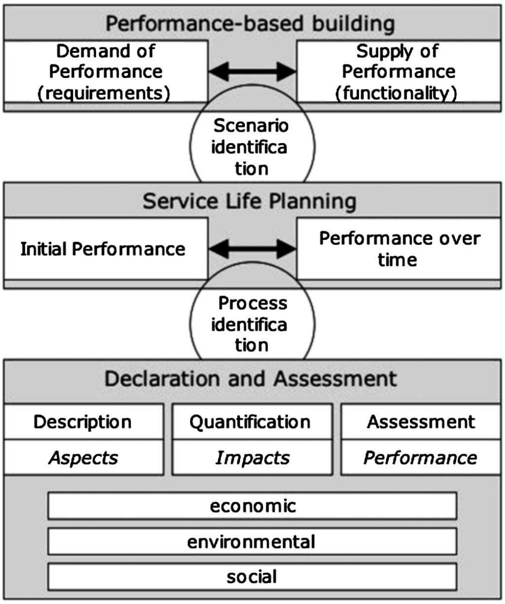


FIG. 2—*The sequential relationship of the concepts of performance-based building, service life planning and declaration, and assessment of sustainability aspects of buildings.*

Standardized Methodologies Applicable as Modules

The thematic field including the items "sustainability in building construction," "service life planning/ design life" and "performance-based building" is a focal area of international standardization activities. Together, the standards that are already published or under development benefit from each other, as many of them can be applied within the context of other standards. This means that they provide each other in the sense of methodological modules—when applying these standards, information generated based on one standard can feed into the routines of the next standard.

In the following, two examples are given for the modularity of the standards. The first one aims to explain the methodological context of performance-based building, service life planning, and declaration and assessment of building-related sustainability (see Fig. 2). The second example illustrates the concepts of reference service life, service life estimation and environmental declaration of building products (see Fig. 3).

Modularity Example 1—PBB, SLP, Sustainability

For the establishment of environmental declarations, and for the comparison of different buildings, the functionality of a building serves as the basis of comparison (compare to "functional unit" ISO TC 207 documents). Involving performance-based building as a starting point helps in establishing clear and quantitative performance requirements, which can be used to identify a building design that successfully meets the clients real demands, without providing unrequested surplus functions. Sounding like a banality, the importance of this latter point is illustrated simply by the fact that "additional functions and benefits" of a product are often considered in the interpretation of assessment results. In such cases, the consideration of such functions becomes critical, especially when the initially favored solution did not "win" a comparison.

With the identification of performance requirements, the decision process can relate to and restrict itself to these performance requirements.

Performance-based building (PBB) is, in short, all about handling aspects related to demand of performance (requirements) to the supply of performance (functionality). Service Life Planning (SLP), as

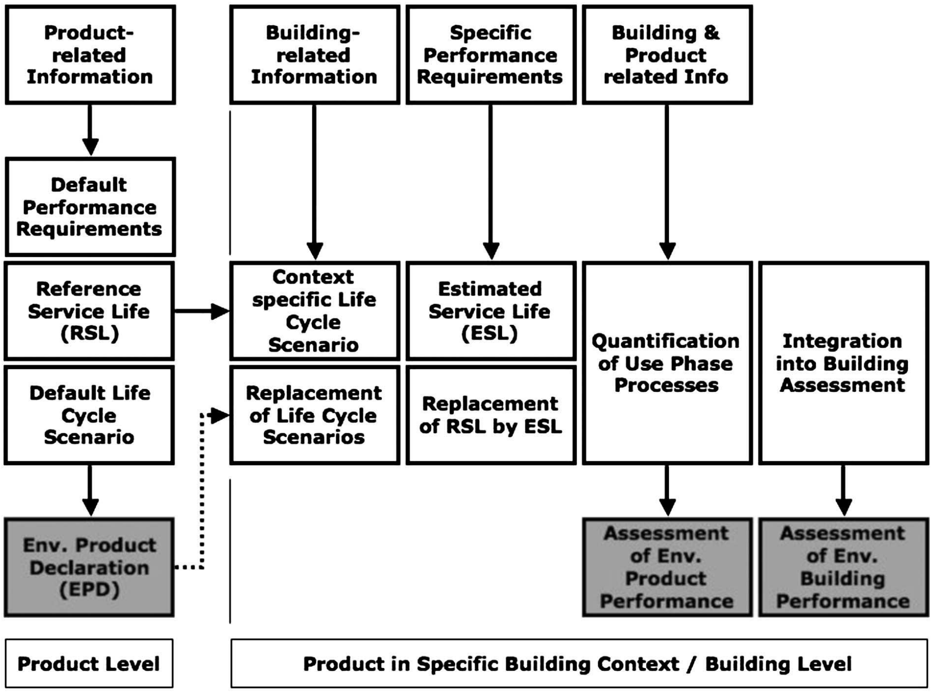


FIG. 3—*Application of ISO 15686 to adapt building product EPDs to scenarios reflecting the conditions of product application in a specific building—the route from product information to assessment of building performance [6,7,10,11,13].*

established in the ISO 15686 series, can relate to the same performance requirements and can use the "supply of performance" as the initial performance provided by a (designed) building. With the "service life" being defined as the period of time during which the performance requirements are met by a building or an assembled system, the link between PBB and SLP becomes obvious. SLP applies product information on long-term performance and establishes a rationale for how long-term performance of a design alternative can be modeled for a specific given design, under specified use conditions, or stated another way: a specific building design with a defined use pattern and under the exposure to an identified environment. Modeling the performance over time allows identifying maintenance processes as well as the timing for replacement of components.

Having identified the maintenance processes, as well as the service life durations or replacement intervals, allows a more detailed description and a subsequent quantification of all processes and activities taking place during the life cycle of the building. This description and identification of the life cycle and the processes is a pre-requisite for the quantification and assessment of impacts; whether these are economic, environmental, or social. In case an assessment concerns performance rather than impacts, again, the assessment will need to relate back to the performance provided by the building and the performance required by the client.

Modularity Example 2—SLP and EPD

An environmental product declaration (EPD) of a building product needs to include the life cycle of the declared product. Performing this description is made difficult by the fact that many building products are not so-called "end-use products"—instead, they are used as an integrated part of another product, in our case in an assembled system or a building. In order to correctly describe the life cycle, this assembled system or building and its exact use conditions would need to be known to those establishing the EPD. As such information is rarely available to the manufacturers of products, they need to rely on one or several scenarios for which an EPD is established. The building specific context and associated information, like the exact use condition, the estimation of service life, identification of maintenance scenarios, and such, are first available when the building applying the product is under design or even in operation. If striving to apply EPDs that correctly reflect the planned application in a building design, the scenarios included in EPDs must be able to be verified as to their congruence with the planned situation. If necessary and reasonable, some assumptions and scenarios may need to be replaced with other more suitable scenarios. Enabling such replacement of scenarios requires a systematic approach applying common boundary definitions of scenarios, as otherwise the risk for double counting or the risk for incompleteness would increase.

Discussion

Success Factors for Standard Application

The standards described in this article are procedural standards. They do not provide the "best solution," but they help to identify the issues to consider in order to reach the objectives of sustainability in building construction.

With the existence of the standards as such, only the very first step of bringing the building and construction sector towards sustainability has been taken. Standards do not themselves solve problems, but they help actors on their way to solve problems associated with sustainability aspects of buildings.

The standards are not mandatory unless a national standardization body adopts them as a national standard, or through clients demanding their application, they can become mandatory on a project-by-project basis, or for a specific client category.

Sustainability is a highly political subject and the approaches to address the issues vary largely between countries, stakeholders, and individuals. To move from international political agendas to projects that are in line with these agendas, sectorial and/or regional interpretation, or both, of the global agendas are needed, e.g., as identified in the CIB Agenda 21 on sustainable construction [3] and the CIB & UNEP-IETC Agenda 21 for sustainable construction in developing countries [4].

The political ambition to move towards sustainability must lead to action within the construction sector, identifying ambitious objectives and targets, and needs to ensure that these are included in planning and management of the sector's activities and products.

For their successful application, the targets and goals need to be expressed in clear and measurable or verifiable performance requirements. First this allows developers and designers to communicate the qualities of their designs relative to these targets.

Designers face a multitude of problems for such communication, related to the availability of reliable information at the stage where highly significant decisions about the building design are being made. In addition, the designers and other stakeholders need to agree on common targets and have the same understanding of the issues. The commitment of organizations and individuals is often decisive for the success, but by no means the subject of standardization in this field.

To become operational, the procedures established in the ISO standards need to be integrated into business models that are applied in the building sector. These models may be on the supply side of sustainability information (such as building product EPDs) or on the demand side (application of information in the design and maintenance of buildings).

Towards this background, the EU research project STAND-INN is investigating the possibilities to integrate "sustainability standards" into the IFC format (international foundation classes)—an established communication format that helps various design and engineering tools communicate object-based information among each other. Successfully linking sustainability information into these processes is regarded as a precondition for widespread application of the ISO standards.

To a great extent, the development of methodology and information modules is related to three core aspects of the products of the building and construction sector:

a. The difficulty to identify and describe the real product life cycle. Product-related information can usually only be provided by the manufacturer or other organization responsible for or related to the design, manufacture and distribution of products. In order to establish information on life cycle stages following the production stage, information is either based on an anticipation of how the product is going to be used (a scenario) or on information on how the product typically is used (statistics).

b. The availability of information on the real performance of the product. The performance of products is very much dependent upon the context in which they are applied (the building) and what service and functionality that building is to provide (performance requirements).

c. The most decisive building design decisions are being made in the early design stages.

At these early stages, however:

- information for specific products is available based on life cycle scenarios reflecting a generic building (e.g., in EPDs); meanwhile the products are not yet specified for the developing building design;
- generic product information is being used; and
- a correct description, quantification, and assessment of performance and sustainability aspects of a building needs to be based on specific product and specific building information.

In order to avoid having to conduct several building assessments, e.g., once in the early sketch stage, once in the detailed design stage, and once on completion of the building, and also to avoid the requirement to multiply the efforts of inserting information into assessment tools, it becomes a practical requirement that the replacement of

a. generic product information with specific product information

b. generic building model with specific building model

c. default performance requirements with real performance requirements

d. default scenarios with specific scenarios is handled more or less automatically with the evolving design and specification of the building. For such automatic replacement of scenarios and information modules, it is necessary that information be structured into predefined modules with a clarity that allows the transformation of information to the specific design. Consequently, we are looking at modular information and at methodologies that enable the transformation of the modular information from one scenario to another.

Acknowledgments

The content of this paper is based on years of discussions with participants of the mentioned ISO and CEN standardization committees and we acknowledge all valuable contributions and ideas we have received. The international participation of experts from various backgrounds is recognized as a necessary precondition—to address sustainability issues.

References

[1] ISO DIS 15392, "Building Construction—Sustainability in Building Construction—General Principles," International Organization of Standardization, Geneva.

[2] "Our Common Future," Brundtland Commission Report to the United Nations, New York 1987.

[3] Bourdeau, L., Ed. "Agenda 21 on Sustainable Construction," CIB Report Publication 237, Rotterdam 1999.

[4] du Plessis, C., Ed. "Agenda 21 for Sustainable Construction in Developing Countries—A Discussion Document," CIB & UNEP-IETC, Pretoria 2002.

[5] Williams, A., keynote presentation to the ISO/TC59/SC17 plenary, Lyon 2004.

[6] ISO 15686-1:2000 (E), "Buildings and Constructed Assets—Service Life Planning-Part 1: General principles," ISO 2000.

[7] ISO 15686-2:2001 (E), "Buildings and Constructed Assets—Service Life Planning-Part 2: Service life prediction procedures," ISO 2001.

[8] ISO 15686-3:2002 (E), "Buildings and Constructed Assets—Service Life Planning-Part 3: Performance audits and reviews," ISO 2002.

[9] ISO 15686-4, "Buildings and Constructed Assets—Service Life Planning-Part 4: Data requirements" (in preparation).

[10] ISO 15686-5, "Buildings and Constructed Assets—Service Life Planning-Part 5: Life cycle costing" (in preparation).
[11] ISO 15686-6:2004 (E), "Buildings and Constructed Assets—Service Life Planning-Part 6: Procedures for considering environmental impacts," ISO 2004.
[12] ISO 15686-7:2006 (E), "Buildings and Constructed Assets—Service Life Planning-Part 7: Performance evaluation for feedback of service life data from practice," ISO 2006.
[13] ISO 15686-8, "Buildings and Constructed Assets—Service Life Planning-Part 8: Reference service life and service life estimation" (in preparation).
[14] ISO 15686-9, "Buildings and Constructed Assets—Service Life Planning-Part 9: Guide on the inclusion of requirements of service life assessment and service life declaration in product standards" (in preparation).
[15] ISO 15686-10, "Buildings and Constructed Assets—Service Life Planning-Part 10: Levels of functional requirements and levels of serviceability — Principles, measurement and use" (in preparation).

Journal of ASTM International, Vol. 4, No. 7
Paper ID JAI101070
Available online at www.astm.org

William E. Kelly[1]

Introducing Standards and Sustainable Design

ABSTRACT: The ABET Engineering Criteria require a capstone design project where students use "appropriate engineering standards." One of the ABET design constraints that students must consider is "sustainability." The new United States Standards Strategy has as one of its goals to "establish standards education as a high priority within the United States private, public and academic sectors." The first Fundamental Canon of the ASCE Code of Ethics states in part that civil engineers "shall strive to comply with the principles of sustainable development in the performance of their professional duties." ASTM E 2432-05 Standard Guide for General Principles of Sustainability Relative to Buildings provides a framework for organizing student design projects to accomplish multiple objectives. However, IEEE's experience in introducing standards in senior design courses indicates that the senior year may be too late and that the introduction to standards should occur in the first or second year. The purpose of this paper is to outline strategies for including standards and sustainability in courses throughout curricula to build the experience, knowledge, and interest necessary to fulfill the ABET capstone requirements in a meaningful way.

KEYWORDS: accreditation, engineering education, standards, sustainability

Introduction

Under the leadership of the U.S. Government, green buildings are becoming widely accepted in the United States. Some Federal government agencies now require the Leadership in Energy and Environmental Design (LEED) certification of the U.S. Green Building Council (USGBC) for all new buildings [1]. The ASCE Code of Ethics calls for civil engineers to incorporate the principles of sustainable development in their practice [2]. Green building processes are reasonably well developed and incorporate currently accepted principles of sustainable development.

The American Society of Civil Engineers (ASCE) Policy 418 entitled the "Role of the Civil Engineering in Sustainable Development" outlines actions that are broader than buildings [3]. To address this, the ASCE Committee on Sustainability has launched a program on Practice, Education and Research for Sustainable Infrastructure (PERSI) [4].

ASCE's efforts are currently directed at sustainable infrastructure but introducing students to best practice for sustainable building design would be a reasonable first step. This is true because sustainable building design and construction practices are reasonably well established and the general procedures would apply to many infrastructure projects.

Building design is a common topic for capstone design projects and it would be reasonable to require that the building be sustainable. With the LEED procedures and a plethora of Federal and state government reports on green building and sustainable design and construction, there is a great deal of material available for students to use as background in such projects.

Most engineering program in the U.S. are accredited by ABET and have to satisfy the ABET Criteria for Accreditation of Engineering Programs [5]. Criterion 4 requires that students use "appropriate engineering standards and multiple realistic constraints" in the culminating major design experience. A list of realistic constraints is provided as part of Criterion 3(c) and the list includes "sustainability." However, if students are going to use appropriate standards in the capstone design course and understand how the various ABET constraints such as sustainability can affect design they must be introduced to these topics earlier in their programs. In fact in the same sentence requiring standards, Criterion 4 requires that students use skills and knowledge in the capstone that they have acquired in earlier course work [6]. The purpose of this paper is to outline how sustainability and standards can be incorporated into general engineering

Manuscript received March 2, 2007; accepted for publication June 26, 2007; published online August 2007.
[1] Professor, Department of Civil Engineering, School of Engineering, The Catholic University of America, Washington, DC 20064, e-mail: kellyw@cua.edu

and science courses to lay the groundwork for the culminating major design experience.

Standards Codes and Ordinances

For a general introduction to standards, students can consult the web sites for ANSI and ASTM [7,8]. An assignment that the author has used for first-year engineering students is to have them complete the ANSI online introduction to standards courses.

All engineering students can be expected to be at least introduced to ASTM standards at some point in their program. Typically, ASTM standards are introduced in materials testing courses where an ASTM standard often provides the standard test procedure. ASCE provides a Commentary as guidance for civil engineering ABET program evaluators and the Commentary notes that evaluators should expect to find that "undergraduates (in the program being evaluated) should be expected to perform tests in accordance with published standards such as ASTM standards and that course materials should demonstrate that appropriate codes and standards are being used in design courses" [9]. ASTM has a number of standards dealing with sustainability in buildings and more are under development. ASTM has also recently started a program to make ASTM standards available to faculty and students at low cost [10].

There are other professional organizations that are also important standards developers for buildings. The American Concrete Institute (ACI) develops codes, standards, and specifications for structural concrete and masonry structures and in 2005 adopted a policy on sustainable development that includes encouraging "the development of sustainable structures through the application of environmentally friendly and sustainable concrete design, materials, and construction" and to "raise the level of awareness and seek support for increased sustainability inside and outside the concrete industry" [11].

There are also numerous trade organizations that develop standards related to buildings. Trade organizations often write standards to encourage the use of specific materials in construction. As could be expected, there are trade organizations that write standards and codes for most building materials and building components and systems.

The American Institute of Steel Construction (AISC) publishes the *Manual of Steel Construction*. AISC and ACI codes and supporting materials are commonly used by civil engineering students in courses in steel and reinforced concrete design, respectively. The Steel Recycling Institute encourages the use of recycled steel in construction [12]. The American Wood Council (AWC) has the National Design Specification for Wood Construction. Although the AWC does not appear to have much related to sustainable design the Canadian Wood Council (CWC) has extensive materials promoting wood in green buildings [13]. The LEED certification gives a credit for the use of certified wood-based materials and products in buildings. The Portland Cement Association (PCA) provides guidance on sustainable design with concrete [14].

Certification of building materials is becoming increasingly important for green buildings. Certification typically means that an organization determines that a product actually meets a specific standard. By researching some of the certification issues related to building materials, students can see how policy issues can affect engineering design.

Green Seal is an organization that writes standards for and certifies materials to its standards. Building material certified includes paints and coatings, and windows and doors. Green Seal has standards for products ranging from building materials to office supplies [15]. The Green Seal web site provides information on Federal laws that require environmental friendly procurement by Federal agencies. For example, Federal Acquisition Regulations (FARs) require that "Agencies shall implement cost-effective contracting preference programs favoring the acquisition of environmentally preferable and energy efficient products and services" [16]. Other Federal requirements are mentioned below. Green Seal makes the case that Green Seal's standards are widely used and recognized by Federal agencies.

GreenGuard Environmental Institute (GEI) is a standards developer that develops indoor air quality standards for products, and buildings [17]. GEI also certifies building materials for avoiding emissions that could affect human health. Indoor air quality is also an important part of the LEED rating system.

Building codes are not standards per se but organize standards for the building industry. Gross defines a code as "a standard or other set of conditions and requirements made mandatory by government bodies, either through direct legislation or through administrative regulation, based on authority granted by a legislative body" [18]. Building codes are administered at the local or state levels and are commonly based on model codes such as those of the International Code Council (ICC) or the National Fire Protection

Association (NFPA). The Federal Government is a special case and construction in the Federal sector is covered by Federal regulations.

The Federal Government has been a leader in the construction of high-performance and sustainable buildings. Some specific drivers include the Energy Policy Act of 1992 and Executive Order 13123 that require substantial reduction in energy use in Federal buildings by 2010 [19]. There is also a requirement in Executive Order 13123 for Federal agencies to apply sustainable principles to all aspects of the design and construction of new facilities. The Whole Building Design Guide collects all Federal building guidance for building design and construction in one place; "the goal of 'Whole Building' Design is to create a successful high-performance building" [20].

Executive Order 13423 was issued on January 26, 2007 revoking Executive Order 13123 and related Executive Orders [21]. The new Executive Order states that it is now the U.S. policy "that Federal agencies conduct their environmental, transportation, and energy-related activities under the law in support of their respective missions in an environmentally, economically and fiscally sound, integrated, continuously improving, efficient, and sustainable manner." Sustainable is defined for use in the order as "to create and maintain conditions, under which humans and nature can exist in productive harmony, that permit fulfilling the social, economic, and other requirements of present and future generations of Americans." It remains to be seen how this order will change the operations of Federal agencies and if, in fact, it is a departure from previous Executive Orders that enabled, and motivated the Federal Government's move to a green building approach. For sustainable buildings it is probably significant that the order states that each agency shall "ensure that (i) new construction and major renovation of agency buildings comply with the *Guiding Principles for Federal Leadership in High Performance and Sustainable Buildings set forth in the Federal Leadership in High Performance and Sustainable Buildings Memorandum of Understanding (2006)*" [22].

When a private-sector standard is adopted in a regulation such as a local building code it becomes a mandatory standard. As pointed out earlier, for all new Federal buildings, GSA requires that they be LEED certified; thus LEED is a de facto mandatory standard.

Local building codes cover all aspects of the construction of buildings. Typically, these are patterned after national model building codes. A number of Federal agencies including the Department of Defense and the General Services Administration (GSA) have adopted the International Code Council's (ICC) International Building Code (IBC). Many building codes that apply at the local level are statewide codes. Building codes are intended to protect the public by ensuring the buildings are constructed to minimum standards. Building codes do not necessarily ensure that buildings and building systems perform at optimal levels. Since energy performance is an important part of achieving overall sustainability, some states have adopted energy standards specifically to improve the energy efficiency of buildings; California is a good example.

Site work and site engineering are commonly covered by ordinances that incorporate standards and specifications [23]. There are no national model ordinances comparable to the model building codes. The USEPA has model ordinances for use in developing local ordinances for erosion and sediment control and storm water management. All of the EPA model ordinances are on a web site that includes model ordinances for land planning and protection of water and other natural resources. The ordinances include language for model ordinances and examples of ordinances from around the country [24].

Zoning ordinances affect all aspects of buildings. EPA, through its Smart Growth initiative, is disseminating information on model zoning ordinances [25]. There are also numerous model provisions that have been proposed for incorporation into local ordinances. For example, the American Wind Energy Association has a model provision intended to promote the use of small wind energy systems [26].

The International Organization for Standardization (ISO) is a standards developer with the ISO 9000 family of quality system standards probably the most well known. ISO 14001 is the standards for environmental management systems that organizations can be certified or registered to. Environmental and quality management systems are increasingly important in the constructed environment with a range of firms in the construction sector becoming ISO 9001 and 14001 certified. It will be shown later that ISO 14040—the life cycle analysis standard—is an integral part of the green building process. It is probably significant that Executive Order 13423 reinforces the requirement that Federal agencies implement an environmental management system although not necessarily ISO 14001.

De facto standards setting processes are not common in the construction sector but the LEED standard is an example of one. Adherence to the LEED standard is required by the General Services Administration and a number of state governments but it is a de facto standard rather than a voluntary consensus standard. This is also the case with Green Seal standards. Students should understand the difference between these standards developed in the private sector and the voluntary consensus standards developed by ASTM.

The voluntary consensus process is more common in areas related to the constructed environment. Standards that are most closely related to civil engineering practice generally are related to public welfare—health, safety, and the environment—and may often be indistinguishable from regulations. It is also common practice for regulations to incorporate standards by reference. For example, most building codes, which are mandatory regulations in their jurisdiction, reference ASCE's standard for minimum design loads.

Identifying Applicable Standards

Sustainable building design and construction is a rapidly evolving field and new standards are being continually proposed and written. One of the best ways for engineers and architects to stay abreast of what is happening is to become active in a standards development activity related to building sustainability. Students should be introduced to these activities as opportunities for "life-long learning." The U.S. Green Building Council has recently started a program called the Emerging Green Builders (EGB). The EGB program brings students and young professionals interested in green building together with the goal of developing future industry leadership. Activities include a national green building design competition, local chapters, and resources for university programs to introduce green building concepts [27].

A useful tool to assist students in finding standards is ANSI's NSSN [28]. Students could search for standards and standards-related information using "sustainability" as the key word. Another good resource is the IHS Inc. site [29]. Searches of both sites using the terms: sustainability, sustainable, and green all yielded relevant documents including a number of standards.

There are ASTM standards directly related to sustainability with more under development. A search of the ASTM site using the keyword "green" yielded two active standards on green roofs and three standards under development related to green roofs. The Library of Congress has a booklet on green roofs which suggests how much interest there is in this topic [30]. Green roofs are visible features of buildings that could be used to introduce students to green building concepts. In Washington, DC, there were reportedly (late 2006) seven new green roofs and more on the drawing boards.

Simple keyword searches will ensure that students quickly find relevant information and begin to make important linkages. For example, ASTM E 2114-06 Terminology for Sustainability Relative to the Performance of Buildings references four other ASTM standards and one ISO standard. As Salamon points out, finding information on the "soft" aspects of design is an important skill for students to develop and practice [31]. Many of the "soft" design constraints that students must consider in the capstone design experience have applicable standards or standards aspects. Students will only be able to effectively research these aspects for the capstone project if they have developed and practiced these skills earlier.

ANSI has been supporting the EPA P3 competition [32]. Part of the ANSI effort is to identify standards that would support green products and help students connect with organizations with green product standards and encourage students to use them in their designs. Students can search the P3 project site to see how standards have been used or where there are opportunities to use there standards [33].

Engineering students are commonly introduced to standard testing methods in introductory laboratories in materials, soils, structures, and water and wastewater. Although introductory laboratory manuals often include standard testing procedures, students should be made aware of the appropriate engineering standards and possibly even asked to look them up in the library or online. In looking up an ASTM standard for a particular test, the student would be exposed to a universe of test methods and standards covered. It would be very easy to search for the appropriate standards on the ASTM website and then find and read the actual standard in most engineering libraries. All university engineering libraries can be expected to have a recent complete set of the ASTM standards. It is interesting in this respect that the Canadian Accreditation Criteria actually require that all engineering libraries have a complete set of standards and codes to support their accredited engineering programs [34].

Design

The only ABET requirement for standards is to use "appropriate standards" in the culminating design experience. The objective here is to highlight connections and opportunities to make the connection between sustainable design and standards. The recent book by Kibert provides an excellent overall introduction to sustainable design and construction of green buildings [35]. The book is keyed to the LEED—New Construction (NC) version 2.1 standard. The LEED template, which is available on the web, would provide a good tool for organizing a design project on a sustainable building [36].

The LEED rating system establishes criteria in six areas: sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor air quality, and innovation and design. Students should be made aware of how principles of ecology inform and are reflected in LEED—e.g., the use of natural materials and the recycling of materials in natural systems—and the systems aspects of buildings. Today's buildings are very complex human-built systems and these systems will only become more complex as intelligence is added to monitor and manage buildings for optimal performance.

It is not appropriate to look at all aspects of building systems in introductory analysis courses such as hydrology, but a more focused approach makes it possible to introduced aspects of standards and sustainable design at almost any point in a curriculum. One approach would be to focus on one aspect of a building such as site development or materials in appropriate analysis courses.

In an introductory hydrology or environmental engineering course storm water management could be a topic discussed from either the quantity or water quality perspective. A facility to manage storm water runoff from a new building would come under LEED sustainable sites credit 6.1 and 6.2 storm water design—quantity control and storm water design—respectively.

In water supply and wastewater courses, students could look at harvesting rain water and the reuse of gray water that come under the LEED category of Water Efficiency and credits dealing with water use reduction and innovative wastewater technologies.

By looking at the water aspects of site development and water efficiency, it is possible to make connections to some of the broader issues of sustainable development. Students at the Catholic University of American (CUA) recently organized a chapter of Engineers Without Borders and have been particularly interested in techniques for rainwater harvesting for use in water supply projects in developing countries.

An alternative to LEED for organizing a building design project would be the *Whole Building Design Guide*. The WBDG is stressed here for several reasons. First, it is freely available and updated on a regular basis. Second, it includes explicit links to relevant codes and standards and although these links are not always comprehensive, they are an excellent starting point for students and are sufficient in some areas. Third, the WBDG is accessible through a comprehensive portal for building design.

There are eight WBDG design objectives. These are: accessible, aesthetics, cost effective, functional/operational, historic preservation, productive, secure/safe, and sustainable. According to the WBDG, each of the objectives is important and contributes to a good project [37]. The WBDG portal has a page for each of the objectives. In that the purpose of this paper is to make the connection between standards and sustainability, only the sustainability objective will be considered.

A design guidance section is accessed from the main page and it is organized into: building types, space types, design disciplines, design objectives, and products and systems.

Parking facility is one of the building types listed. Campuses are always in need of more parking, and a green parking facility design or redesign would be a possible student project. The parking garage constructed for the Catholic University law building in 1995 has a green roof. A green roof is one way of optimizing site potential for a parking facility; optimizing site potential is one of the principles to be applied under the sustainable design objective [38].

Under space types, the different spaces that can be expected in buildings are discussed. Two of the space types deal with parking: parking outside and parking surfaces. Under sustainable for outside parking, the emphasis is on storm water management. For parking surfaces under sustainable the opportunity for site improvements include: improving ground cover to reduce heat island effects and storm water management.

Each design guidance section includes references to relevant codes and standards. Here the references are to the GSA *Facilities Standards for the Public Buildings Service*. The GSA document contains policy and technical criteria to be used in the programming, design, and documentation of GSA buildings and can be downloaded from the GSA website. The second reference is to the ICC Building Code which has been adopted by GSA and most Federal agencies. Another referenced standard is the *Manual on Uniform Traffic Control Devices for Streets and Highways: Revision 4—March 1996*. Finally, the Illuminating Society of America's (ISEA) standard for outdoor lighting is referenced.

Sustainable is the last of the eight design objectives. Under sustainable there are five related topics: optimize site potential; optimize energy use; protect and conserve water; use environmentally preferable products; enhance indoor air quality; and optimize operational and maintenance practices. Codes and standards noted as relevant include several ASTM standards [39].

The first standard referenced is ASTM E 2432 Standard Guide for General Principles of Sustainability Relative to Buildings. This standard notes that sustainability incorporates three types of general principles: environmental, economic, and social. ASTM E 2432 discusses these issues as they relate to buildings. This standard references several other ASTM standards and the ISO standard for life cycle assessment (ISO 14040). According to ASTM E 2432, the principles listed in the standard are applicable to all scales of building projects including infrastructure systems and to all life-cycle states of a building including deconstruction and waste disposal [40]. This is a standard that all civil engineering students should be introduced to.

Another reference under relevant codes and standards is the Energy Policy Act of 2005. This effectively demonstrates political and social factors as constraints in engineering design. The Energy Act is 550 pages long and it goes well beyond buildings. In fact, there appears to be only one reference to green buildings in Section 1829; the requirement is for improving energy and water savings measures in Congressional buildings using new technologies to implement effective green building technologies [41].

Under *optimize site potential* the recommendations are as follows: minimize development of open space; consider energy implications in site selection and building orientation; reduce heat islands using landscaping and building design methods; minimize habitat disturbance; restore the health of degraded sites; design for sustainable transportation; and balance site sustainability with site security/safety.

Approaches for reducing heat island effects are to use light-colored materials on roofs to reduce energy loads and to consider incorporating green roofs. For reflective roofs the roof should be constructed of products that meet or exceed the Energy Star standard. Green roofs have already been mentioned. One of the relevant codes and standards listed is the UFC 3-210-10 Design: Low Impact Development Manual (10-25-2004).

The next section is to *optimize energy use*. Energy is such an important part of sustainability that all engineers should understand how buildings use energy and where there are opportunities for savings. Junnila and Horvath present results of life-cycle assessments for newly constructed buildings in Europe and the United States. The authors break the assessment down into: materials, construction, use phase, maintenance, and end of line. For energy, the breakdown is that almost 83 % of the energy usage comes in the 50-year use phase. The second heaviest usage is 9 % for materials used in building construction [42].

The next section is to *protect and conserve water*. In construction, Federal agencies are expected to "Reduce, control, and treat surface runoff; use water efficiently through ultra-low flow fixtures, elimination of leaks, water conserving cooling towers, and other actions; improve water quality; for example eliminate lead-bearing products in potable water; recover nonsewage and gray water for on-site use; and establish waste treatment and recycling centers; and apply the FEMP Best Management Practices for Water Conservation" [43].

This is an area closely related to optimizing site potential where the engineering or site development specialist would be expected to play an important role. Relevant codes and standards that are referenced include the Uniform Facilities Guide Specifications UF-01356A Storm Water Pollution Prevention Measures (01-2006) [44]. This specification deals with control of sediment during construction and references a number of ASTM standards for geosynthetics related to materials and to practices.

The next section is entitled *use environmentally preferable products*. Executive Order 13101, "Greening the Government Through Waste Prevention, Recycling, and Federal Acquisition," directs Federal agencies to use recycled content [45]. When developing specifications, product descriptions, and standards, agencies must consider a broad range of environmental factors including: waste prevention, recyclability, the use of recycled content, environmentally preferable, and bio-based products, life-cycle cost, and ultimate disposal. This is a complex topic and some of these concepts should ideally be introduced to students in materials courses. One of the relevant codes and standards listed is ASTM E 2129 Standard Practice for Data Collection for Sustainability Assessment of Building Products [46]. This practice covers collecting data to be used in assessing the sustainability of building products for use in commercial and residential buildings. The standard references a number of other standards including a number of ASTM standards.

Executive Order 13101 has been replaced by Executive Order 13423 but the requirements for agencies to use sustainable environmental practices in acquisition of goods and services suggests no fundamental change is likely in the short term.

Although students may not get into the evaluation of the sustainability of building materials they should find NIST's BEES tool useful for understanding and exploring the different environmental impacts of building materials. BEES is an acronym for "Building for Economic and Environmental Sustainability." BEES is a tool for assessing materials for both their energy content and their environmental impact [47].

The final section deals with *indoor air quality*. This is an important criterion with respect to the LEED rating system. Although the civil engineer would not normally be expected to play much of a role in this aspect of design, they should appreciate the relationship between materials and indoor air quality and human health.

Examples

A number of ways have been suggested for bringing standards and sustainability into engineering curriculum. The three examples that follow are intended to show that it is possible to do this in many different ways.

Biotretention

During the fall 2006 semester, a class in environmental science and engineering investigated the installation of bioretention facilities on the CUA campus. A simple search on the web indicated that many jurisdictions are establishing guides, standards, or collections of best practice for bioretention facilities.

The Low-Impact Development Center, with support from the US EPA, has developed specifications for bioretention facilities. According to the website, "This site has been developed through a Cooperative Assistance Agreement under the US EPA Office of Water 104b(3) Program in order to provide guidance to local governments, planners, and engineers for developing, administering, and incorporating Low Impact Development (LID) into their aquatic resource protection programs" [48]. According to the site, "Bioretention facilities are small landscaped basins intended to provide water quality management by filtering stormwater runoff before release into storm drain systems. This work shall consist of installing bioretention facilities as specified in the Contract Documents, including all materials, equipment, labor and services required to perform the work."

Standards referenced include ASTM standards for aggregates and limestone and the test method for soil pH. The LID site notes that "This project includes specifications for four (4) commonly used LID IMP's. The purpose of these specifications are to provide public works agencies with a foundation to develop their own LID standards and specifications. The specifications are written using AASHTO and or ASTM criteria wherever possible in order to allow for communities to prepare consistent bid packages with commonly available materials."

The Federal Green Construction Guide of Specifications now includes draft specifications for constructed wetlands, rain water harvesting, storm water management with compost, and green roofs with vegetation and membranes [49]. These draft specifications were open for comment until March 2007 and would have provided a good opportunity for students to see how the comment process works. Students at CUA did extensive research on storm water management approaches focusing on experience with actual bioretention projects in their home communities and might have been prepared to comment on the draft specifications after their research.

Although the bioretention assignment is a fairly simple example, it has many of the features that would be expected in a more complex project. Sustainability is already a main theme of this introductory course in environmental engineering and science for university honors students and it was only necessary to bring in the standards aspects. In fact, the students were able to discover the standards aspects by looking at what constitutes good practice, how specifications were written in their community, and so on.

Strength of Materials

The second example is for a required course in strength of materials for civil engineers. Salamon provided an approach for incorporating standards in a course in strength of materials at Penn State and this application built on his experience. The course at CUA is not linked to a laboratory course and at this point in their programs, students have had little or no exposure to engineering testing standards. Thus it is necessary to introduce standards and this can be done by relating standard testing methods to the theory students are learning. In fall 2006, the author provided an introduction to standards in the required freshmen design course so that in the future, students will have a basic background in standards.

Sustainability is not normally a theme in an introductory course in strength of materials, so bringing sustainability in requires some extra effort. The author has developed and taught a course on the principles of sustainable development at the senior-graduate level that included sections on construction materials and green buildings. However, many feel that it is necessary to infuse professional practice concepts like sustainability into existing required courses rather than treat them as separate courses. This is also true for standards—it is necessary to include standards in existing required courses at appropriate points.

In that this was the first time I had taught strength of materials in a number of years, I started with a blank slate and made an effort to bring both standards and sustainability into the course. A website was developed for the course which includes sections on green construction materials and standards.

The relationship between standards and theory is straightforward and many textbooks identify lists of standards relevant to construction materials. The next step is to connect particular standards to the theory students are studying. Finally, it is necessary to develop some problems or exercises that lead students to understand the various connections between strength of materials and standards. It is also useful to introduce the concept of specifications; a good example is the ASTM specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement.

The connection to sustainability is not direct in a strength of materials course and the course could easily be taught without reference to sustainability. However, if an effort is made to bring sustainability in, as Salamon did with design, students could gain an understanding of the increasingly important role that this “soft” constraint is playing in building design and construction.

This is a strength of materials course for civil engineering students, I focus on the construction materials—wood, metals, concrete, and plastics for examples, and there are green specifications relevant to each of these materials [50]. For the students’ convenience, I put copies of these green specifications on the course website.

Each specification includes a discussion of resource management, toxicity/IEQ, and performance as they relate to the material that is the subject of the specification. Performance is directly related to the normal subject material in strength of materials; the other two topics are not.

One strategy would be to have the students review and summarize the resource management and toxicity/IEQ issues for a material of their choice. Students could write a short paper and make an in-class presentation. This is probably a reasonable exposure given the primary focus of this course. This would also be an opportunity to look at these issues with BEES.

For recycled plastic, there are performance issues that relate directly to topics in mechanics that could be explored in more depth. There also appears to be some issues related to structural performance of alternative agricultural-based products that could be explored if there was student interest.

The performance issues for plastic lumber are excessive creep and excessive deflection. The concept of creep may be included in an introductory strength of materials course and deflection is a topic that is normally covered. Krishnaswamy and Lampo describe development of standards for recycled plastic lumber in a paper which won first place in the World Standards Day paper competition in 2001 and was reprinted in ASTM’s *Standardization News* [51]. This paper plus the supporting ASTM standards provides sufficient background material to include plastic lumber as a special topic in a strength of materials course to illustrate a connection between standards and sustainability in the context of a strength of materials course.

It is also possible to use the performance of plastic lumber as an introduction to more advanced topics such as the use of reinforcement in plastics and its implications for performance versus sustainability. Dematerialization will be an important part of our transition to sustainability and students could explore the role that new construction materials could play.

Analytic Hierarchy Process

The last example is one that has not yet been introduced, but is one that could be brought directly into a capstone design course or possibly introduced in an introduction to engineering course.

The Analytic Hierarchy Process (AHP) is incorporated in BEES and is also a standalone ASTM standard; Standard Practice for Applying the Analytic Hierarchy Process (AHP) to Multi-attribute Decision Analysis of Investments Related to Buildings and Building Systems. AHP is a method for rating alternatives against multiple criteria. The AHP method is briefly outlined by Winston who provides a spreadsheet solution for a simple example [52]. The multiple objectives to be compared do not have to be quantifiable. It is first necessary to determine weights for the various objectives by performing a pairwise comparison against the overall objective. Typically the overall objective would be a design that would yield the best project in the eyes of the owner. One of the objectives for the owner could be sustainability. Depending on how the owner rates sustainability, its weight could vary from zero to a near one.

After the weights for the objectives are determined, then the alternative designs are rated pairwise for each objective. The results are then normalized and an overall rating for each alternative design is calculated. If there are clear differences in the ratings, one design may be selected as superior and the best choice. If the ratings are close, alternative designs may be rated equally good. A sensitivity study can be done to test the sensitivity to weighting. There is also a check for consistency. Consistency recognizes that the pairwise comparisons are subjective and may not be consistent from individual to individual or for an individual at different times.

The ASTM standard is described for the case where there are multiple levels of objectives. For the simple case outlined by Winston and implemented in a spreadsheet there is only one level of objectives (attributes in the ASTM standard). Multiple levels can be solved with a spreadsheet but that approach can become cumbersome. The examples described in the ASTM standard are explained using a computer program that is available from ASTM.

A student should be able to implement a simple problem with one layer of objectives in a spreadsheet and will gain a basic understanding of the AHP method by doing this. The AHP is a powerful tool for bringing in design objectives like sustainability and its implementation in a spreadsheet format is a possibility for inclusion in an undergraduate design or introduction to design course.

The author has developed some preliminary design examples in a spreadsheet format and made them available for student use. The spreadsheet uses the approximate solution method presented by Saaty which is easy to follow and explained in some detail by Saaty [53]. The examples are set up for seven objectives and three alternatives.

Building skills in the use of engineering tools like spreadsheets starts in the first year and introduction to the AHP method via spreadsheets could be done in a first year introduction to engineering design course. It would actually accomplish multiple objectives including introduction to standards, providing students with an introduction to a powerful design tool, and building spreadsheet skills.

Conclusions

For students to effectively use engineering standards and address sustainability in their culminating design experience, they must be continually exposed to these topics starting early in their academic program.

Although it has been shown that it is relatively easy to link sustainability and standards to various aspects of design, specifically building design, it requires extra effort by faculty members to accomplish this. There is little in the way of textbook materials that are available off the shelf.

To ensure that standards and sustainability are infused into university curricula there is a need for supporting course materials. ASTM has made a start with its “Come Explore the World of Standards” modules. These modules should be useful in a number of engineering courses including an introduction to engineering course and a senior seminar course. The next step would be to develop some modules specific to appropriate engineering science courses such as strength of materials and even nonengineering courses such as environmental science.

References

[1] U. S. General Services Administration (GSA), “1.6 Environmental Policies & Practices,” http://www.gsa.gov/Portal/gsa/ep/contentView.do?contentType=GSA_BASIC&contentId=14167&noc=T (accessed March 2006), 2005.

[2] ASCE Code of Ethics, http://www.asce.org/inside/ethics.cfm (accessed February 2007).

[3] American Society of Civil Engineers (ASCE), "The Role of the Civil Engineering in Sustainable Development," ASCE Policy Statement 418, http://www.asce.org/pressroom/news/policy_details.cfm?hdlid=60 (accessed April 2006).
[4] ASCE PERSI Report, https://www.asce.org/files/pdf/instfound/june05report.pdf (accessed February 15, 2007).
[5] ABET Criteria for Accrediting Engineering Programs, Effective for Evaluations During the 2006–2007 Accreditation Cycle, http://www.abet.org/forms.shtml (accessed February 2007).
[6] ABET Criteria for Accrediting Engineering Programs, Effective for Evaluations During the 2006–2007 Accreditation Cycle, http://www.abet.org/forms.shtml (accessed February 2007).
[7] ANSI Standardslearn, http://www.standardslearn.org/home/ (accessed February 15, 2007).
[8] ASTM Handbook of Standardization, http://www.astm.org/cgi-bin/SoftCart.exe/NEWS/handbook02/index.html?L+mystore+iail7686+1061332468 (accessed February 15, 2007).
[9] American Society of Civil Engineers (ASCE), "Commentary American Society of Civil Engineers Program Criteria for "Civil" and Similarly Named Engineering Programs Draft #7," http://www.asce.org/public/criteria/commentary.cfm (accessed June 2005), 2002a.
[10] ASTM Program For Students, http://www.astm.org/cgi-bin/SoftCart.exe/studentmember/index.html?L+mystore+nzhl4584+1128544351 (accessed February 15, 2007).
[11] American Concrete Institute (ACI), "American Concrete Institute Information on Sustainable Development," http://www.concrete.org/FAQ/afmviewfaq.asp?faqid=35 (accessed June 2006), 2006.
[12] Steel Recycling Institute, http://www.recycle-steel.org/construction.html (accessed February 14, 2007).
[13] Canadian Wood Council Forest Certification, http://www.cwc.ca/environment/sustainable_buildings/certification/ (accessed February 15, 2007).
[14] Portland Cement Association (PCA), Sustainable Design, http://www.cement.org/buildings/sustainable_design.asp (accessed February 14, 2007).
[15] Green Seal, http://www.greenseal.org/ (accessed February 19, 2007), 2006.
[16] Green Seal, Greening Your Government, http://www.greenseal.org/programs/government.cfm (accessed February 14, 2007).
[17] GreenGuard Environmental Institute (GEI), "GREENGUARD Certification Standards for Low Emitting Products for the Indoor Environment," http://www.greenguard.org/Desktop Default.aspx?tabindex=3&tabid=16, 2006.
[18] Gross, J. P., "Codes, Standards, and Institutions—Pressure for Change," *J. Profl. Issues Eng. Educ. Pract.*, Vol. 117, No. 2, 1991, pp. 75–87.
[19] Executive Order 13123 Greening the Government through Efficient Energy Management, http://www.ofee.gov/eo/archive/eo13123.pdf (accessed February 15, 2007).
[20] NIBS The Whole Building Design Guide, http://www.wbdg.org/ (accessed February 15, 2007).
[21] Executive Order 13423 Strengthening Federal Environmental, Energy, and Transportation Management, http://www.ofee.gov/eo/EO_13423.pdf (accessed February 16, 2007).
[22] Executive Order 13423 Strengthening Federal Environmental, Energy, and Transportation Management, http://www.ofee.gov/eo/EO_13423.pdf (accessed February 16, 2007)
[23] Ben-Joseph, E., "Future of Standards and Rules in Shaping Place: Beyond the Urban Genetic code," Forum, *J. Urban Plann. Dev.*, Vol. 130, No. 1, 2004, pp. 67–74.
[24] USEPA Model Ordinances to Protect Local Resources, http://www.epa.gov/owow/nps/ordinance/index.htm (accessed February 19, 2007).
[25] USEPA Smart Growth Land Development Regulation Publications, http://www.smartgrowth.org/library/byldrtype.asp?typ=12&res=1024 (accessed February 16, 2007).
[26] American Wind Energy Association (AWEA), "AWEA Model Zoning Ordinance: Permitted Use Regulation for Small Wind Turbines," http://www.awea.org/smallwind/documents/modelzo.html (accessed April 2006), 2002.
[27] U. S. Green Building Council, Emerging Green Builders (EGB) Home, http://www.usgbc.org/DisplayPage.aspx?CMSPageID=116 (accessed May 28, 2007).
[28] ANSI NSSN Search Engine for Standards, http://www.nssn.org/ (accessed February 16, 2007).
[29] IHS Standards Search Site, http://global.ihs.com/ (accessed February 16, 2007).
[30] LOC Tracer Green Roofs, http://www.loc.gov/rr/scitech/tracer-bullets/greenroofstb.html.

[31] Salamon, N., "The Use of Standards in an Introductory Design Course at Penn State University," http://www.astm.org/cgi-bin/SoftCart.exe/SNEWS/DECEMBER_2005/salamon_dec05.html?L+mystore+qtfx3964+1171465069 (accessed February 14, 2007).
[32] ANSI P3, http://www.ansi.org/education_trainings/p3/overview.aspx?menuid=9, (accessed February 16, 2007).
[33] USEPA 2006 P3 Award Winners, http://es.epa.gov/ncer/p3/project_websites/2006/2006 awardwinners.html (accessed February 14, 2007).
[34] Canadian Engineering Accreditation Board (CEAB), "Questionnaire for Evaluation of Engineering Programs—Part 1," http://www.ccpe.ca/e/files/acc_Part1.pdf (accessed December 2005), 2005.
[35] Kibert, C. J., *Sustainable Construction: Green Building Design and Delivery*, John Wiley & Sons, Inc., 2005.
[36] USGBC LEED for New Construction, http://www.usgbc.org/ShowFile.aspx?DocumentID=1704 (accessed February 14, 2007).
[37] WBDG Design Objectives, http://www.wbdg.org/design/designobjectives.php, (accessed February 16, 2007).
[38] WBDG Green Roof for Parking Facility, http://www.wbdg.org/design/parking.php (accessed February 16, 2007).
[39] WBDG Codes and Standards References Under Objective Sustainability and Security, http://www.wbdg.org/design/balancing_objectives.php (accessed February 16, 2007).
[40] ASTM Standard E 2432, "Standard Guide for General Principles of Sustainability Relative to Buildings," *Annual Book of ASTM Standards*, Vol. 04.12, ASTM International, West Conshohocken, PA, 2005.
[41] Energy Policy Act of 2005, http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=109_cong_bills&docid=f:h6enr.txt.pdf (accessed February 16, 2007).
[42] Junnila, S. and Horvath, A., "Life-Cycle Environmental Effects of an Office Building," *J. Infrastruct. Syst.*, Vol. 9, No. 4, 2003, pp. 157–166.
[43] WBDG Best Management for Water Conservation, http://www.wbdg.org/design/conserve_water.php (accessed February 16, 2007).
[44] Uniform Facilities Guide Specifications *UF-01356A*.
[45] Executive Order 13101 Greening the Government Through Waste Prevention, Recycling, and Federal Acquisition, http://www.ofee.gov/eo/archive/13101.htm (accessed February 16, 2007).
[46] ASTM Standard E 2129, "Standard Practice for Data Collection for Sustainability Assessment of Building Products, *Annual Book of ASTM Standards*, Vol. 04.12, ASTM International, West Conshohocken, PA, 2005.
[47] BEES, http://www.bfrl.nist.gov/oae/software/bees.html (accessed February 16, 2007).
[48] LID Bioretention Drainage Specification, http://www.lowimpactdevelopment.org/epa03/biospec.htm (accessed February 19, 2007).
[49] WBDG New Suite of Stormwater Management Guide Specifications Available for Comment, http://www.wbdg.org/ (accessed February 16, 2007).
[50] Federal Green Specifications, http://www.wbdg.org/design/greenspec.php (accessed February 16, 2007).
[51] Krishnaswamy, P. and Lampo, R., "Recycled-Plastic Lumber Standards: From Waste Plastics to Markets for Plastic Lumber Bridges," http://www.astm.org/cgi-bin/SoftCart.exe/SNEWS/DECEMBER_2001/wsd_dec01.html?L+mystore+cghy1251+1018390194 (accessed February 14, 2007).
[52] Winston, W. L., *Operations Research: Applications and Algorithms*, 3rd ed., Duxberry Press, Belmont, CA, 1994.
[53] Saaty, T., "Decision Making for Leaders: The Analytic Hierarchy Process for Decisions in a Complex World," University of Pittsburg, Pittsburgh, PA, 1988.

Journal of ASTM International, Vol. 5, No. 2
Paper ID JAI101169
Available online at www.astm.org

Wayne Trusty[1]

Standards Versus Recommended Practice: Separating Process and Prescriptive Measures from Building Performance

ABSTRACT: Rating systems in North America are experiencing a fundamental shift in the way they approach sustainable design, away from a prescriptive methodology toward one that emphasizes quantifiable performance. They are maturing, placing more importance on issues such as life cycle assessment and how to strengthen the link between design forecasts and actual building performance over the long-term. But, they remain an inherent mix of objective and subjective elements—of process, prescriptive measures, and performance—which makes it difficult for them to evolve in their entirety into sustainable building standards. This paper will focus on fundamental issues related to the standardization of sustainable design principles in the context of assessment and rating systems, drawing on the experience of the Green Building Initiative (GBI) American National Standards Institute (ANSI) Technical Committee for Green Globes™. The GBI is the first national organization to take a green building rating system through the consensus-based ANSI process, and its technical committee will examine how process, prescriptive, and performance measures fit in a standard of this nature. For example, experience shows that an integrated design process tends to result in higher performance buildings. However, while it is recommended practice, can it be mandated as part of a standard if it isn't a measure of the building's actual worth? Indeed, can any process be dictated, or would this risk penalizing an exceptional building for something that has nothing to do with sustainability? Likewise, prescriptive measures such as favoring building materials with recycled content do not always deliver the benefits they are widely assumed to have. They are means to an end and should not be treated as objectives in their own right. It is tempting to include prescriptive measures in a standard because they are easy to verify. But do we not then risk perpetuating points of view that, while deeply entrenched, do not contribute positively to actual building performance?

KEYWORDS: building assessment and rating systems, sustainable building, life cycle assessment, building certification

Introduction

There is no question that building assessment and rating systems in North America, Europe, Japan, and other parts of the world have been, and continue to be, central to the rapid increase in awareness of sustainable building. Governments at various levels have seen rating systems as a seemingly straightforward, positive step toward demonstrated concern for and action with regard to the environment. The presumption is that mandating the use of one or more rating systems automatically gets the job done, while concurrently providing a good sound bite. Users of the systems naturally expect high ratings to go hand-in-hand with high performance. Unfortunately, the evidence that performance expectations are being met is not as clear as one might expect or hope; there are highly rated buildings that perform up to their billing, but there are also highly rated buildings that do not perform well at all.

There can be a number of reasons for the divide between expectation and outcome, a divide referred to in U.K. studies as the "credibility gap" [1]. The gap is probably most evident on the energy front, where post-occupancy performance is easily tracked. But there can be other failures damaging to the environment that are not so easily tracked. To some extent, those problems reflect the natural tendency to want simple answers and prescriptive, easy-to-follow directions to what are actually very complex issues. Materials selection is a good example; it is much easier to specify prescriptive paths involving recycled content, the use of rapidly renewable materials, or transportation distances than it is to require a life cycle assessment that focuses on the true environmental performance implications of material choices.

Manuscript received March 29, 2007; accepted for publication January 7, 2008; published online February 2008.
[1] President, Athena Institute, Chair, Green Building Initiative™ ANSI Technical Committee for Green Globes,™ Merrickville, ON Canada

The problem is complicated when rating systems incorporate well-meaning but sometimes questionable requirements, and put them on the same or close to the same level as critical issues such as global warming. Bicycle racks are a good idea in terms of occupant mental and physical well-being, but they are not likely to have energy use and global warming impacts remotely close to those associated with building operations. That fundamental difference in importance has to be explicitly recognized and dealt with in implicit or explicit weighting given to different credits in a rating system.

The problem is further complicated when we use the word "standard" in relation to assessment and rating systems. A rating system encourages and rewards best practices across several fronts (e.g., site selection and water use), but not all best practices should be classified as a standard in any regulatory sense of the term. We can think of a rating system standard in the sense of an agreed level of quality or attainment, but not necessarily in the sense of a required level. The guidelines developed for the State of Minnesota have clearly recognized this problem by avoiding the idea of rating altogether. The state's Sustainable Building Guidelines instead comprise required and recommended practices for all state-funded buildings.

This paper explores these issues—the relative weighting of "good ideas," prescription versus performance, and the place for standards setting processes—from the perspective of the current Green Building Initiative™ (GBI) effort to take the Green Globes™ environmental assessment and rating system through a formal consensus-based American National Standards Institute (ANSI) process. As the first national organization to take this step, GBI and its technical committee are examining how process, prescriptive, and performance measures fit in a standard of this nature.

The GBI ANSI Process

The mission of the GBI is to accelerate the adoption of building practices that result in energy-efficient, healthier, and environmentally sustainable buildings by promoting credible and practical green building approaches for residential and commercial construction. In 2005, the GBI became green building's first ANSI-certified Standards Development Organization and proceeded to put the Green Globes rating system through the rigorous ANSI process following preset procedures.

A balanced 30-person committee was structured from a list of applicants representing government, the academic community, industry, and other stakeholders. Ten members of the committee are from the producer sector, ten represent users of the system, and ten represent the general interest category of stakeholders. ANSI procedures dictate that votes can only be held when the committee is balanced, with specific quorum and affirmative vote percentages required to pass resolutions. For a "no" to be considered persuasive, it must be accompanied by a reason and overturning such a "no" vote requires a larger than normal percentage of "yes" votes. Once the full rating system has been through the committee and affirmed, it will be subjected to public review with clear provisions for an appeal process in the event of negative reactions to any part of the system. This full ANSI committee meets a minimum of four times a year, three times by teleconference and once face-to-face.

After the full committee was struck and had met, it was agreed that a series of subcommittees were required to focus the seven separate parts of the rating system. Each subcommittee is chaired by a member of the full committee, and may have two or three other full committee members. The rest of each subcommittee is made up of other interested stakeholders up to a total of 15 people per subcommittee. Balancing subcommittee interests when selecting from the list of applicants has not been as critical as ensuring the appropriate levels of expertise in each of the subject areas. However, when choices had to be made among applicants with similar expertise, an effort was made to ensure that no industry group dominated any subcommittee. The chairs of the subcommittees form an executive committee under the chair of the full committee. In addition, crosscutting working groups have been formed as necessary, for example to deal with moisture control issues that potentially affect various areas of the rating system. Subcommittees may vote as they see fit, but their basic objective is to make recommendations to the full committee as the formal voting body.

The GBI/ANSI process has been underway for about a year and a half and, as a result of extraordinary effort and dedication on the part of the volunteers at the sub- and full-committee levels, the system will be tabled for a first full letter ballot early in 2008. Shortly thereafter, the system will be released for the first round of public comments.

Weighting

One of the critical issues rightfully raised by the full committee and by every subcommittee is the distribution of points across the various areas of the rating system, as well as across credits within each area. Green Globes has seven assessment areas—project management, site issues, energy use, water use, resource use, indoor environmental quality, and emissions, effluents, and other impacts—across which 1000 points are distributed. The points allocated to any given area are then distributed among the individual credits within that area. To the extent possible, points are allocated to credits on a sliding scale so that efforts in the right direction are rewarded within a rigorous framework. The question is—"how many points should be allocated to each area and how, specifically, should they be distributed?"

To address that question, the full ANSI committee participated in a formal Analytical Hierarchy Process (AHP) at its March 2007 face-to-face meeting. (For an explanation of AHP, visit www.expertchoice.com/customerservice/ahp.html.) Under the direction of Dr. Ernest H. Forman—a Professor of Management Science at George Washington University's School of Business and Public Management and Founder, Chairman and Chief Technology Officer at Expert Choice, Inc.—the committee used specially-designed software to rank the seven assessment areas and determine their relative importance in percentage terms. Those percentages will now be used to distribute the 1000 points across the rating system.

The AHP was also used to determine how points might be allocated across specific environmental impact performance measures within the life cycle assessment (LCA) part of the resource use area. The use of LCA is discussed in more detail below.

Because the number and nature of credits varies considerably depending on which of the Green Globes assessment areas one considers, the AHP process was not suitable for that level of point distribution without a very time consuming and elaborate process. It was decided, therefore, that the individual subcommittees would recommend the most appropriate distribution of points within each area based on their expertise. Those recommendations are, of course, subject to final ratification by the full committee.

The essence of this entire procedure is to transparently apply an accepted, robust consensus methodology to the thorny issue of weighting the disparate components of the rating system.

Prediction Versus Performance

If an energy performance label has been granted on the basis of a building design simulation, and the building fails to perform at the predicted level, then the label tends to be devalued, especially for high profile buildings. Further, legal experts active in the green building arena are warning about the potential for litigation if there is a consistent tendency for buildings to fail to live up to their advance billing. That potential escalates if a rating system label or certificate is cited as the basis for an energy tax credit or other financial incentive.

A recent post-occupancy study of several LEED® (Leadership in Energy and Environmental Design) buildings on the U.S. West Coast illustrates some of the problems associated with dependence on the rating system approach as an indicator of energy performance [2]. Of four new office buildings in the sample, only one had actual energy usage better than the modeled usage, while the other three performed worse than expected. In contrast, three out of four multi-unit residential buildings performed better than predicted; the one that did not perform as well was a building that offered low-income units and received the lowest level of LEED certification. The two new library buildings in the sample both performed better than predicted.

There can be a variety of reasons for these differences, including occupancy behavior and, in the case of the library buildings, person-hours of occupancy. The relevant point is that buildings seldom perform at the simulated level, and problems can be created when performance is poor relative to the expectations created by the granting of a rating.

This is a difficult issue to resolve for new buildings unless a label is granted purely on the basis of prescriptive measures. Otherwise, simulation is the only option. The question, in that case, is—"what simulation and benchmarking approach is likely to be the more reliable?" Discussing and answering that question in any definitive way is beyond the scope of this paper, but there are clearly grounds for debate about the relative merits of an ASHRAE 90.1 approach as required in LEED versus the reference to an actual benchmark such as the Energy Star Target Finder database used by Green Globes. Growing support for the latter was underscored recently by Architecture 2030's call for climate change legislation based on the Commercial Buildings Energy Consumption Survey (CBECS) data, which forms the basis of the Target Finder program.

A prescriptive path, whereby a system credits specific design elements and the installation of equipment, may be the appropriate approach for smaller buildings that cannot afford the more expensive energy simulation approach. There is a research basis for assuming that specific prescriptive measures, ranging from basic orientation through shading, glazing and heating, ventilating and air conditioning choices, can have predictable energy saving consequences. The difficulty of basing a rating or label on this type of measure is the variability that can occur from building to building, and the way in which various measures may combine (or fail to combine) to produce a given level of energy use. In short, how does one verify that a given performance level is likely to be achieved?

Ultimately, I believe the answer is that we have to get past the notion of fully rating buildings immediately after construction and only grant final ratings after at least one year of occupancy. An initial rating could still be granted with regard to site selection, project management, resource use, or other criteria that can be fully assessed immediately after construction. But operational criteria such as energy use, water use, and indoor environmental quality could be the focus of a post-occupancy assessment. This ties to the GBI concept of an assessment continuum—and specifically, that Green Globes for New Construction can be used in tandem with the new Green Globes module for Continual Improvement of Existing Buildings—whereby a system focuses on the full gamut from project initiation through ongoing operations, with a smooth transition from preconstruction through construction to post-occupancy measurement and evaluation. Granting a design/construction rating would at least partially deal with the desire of building developers to get the marketing advantage that comes with a high rating, without promising more than a building may deliver.

If we turn to resource use and product selection, defining "sustainable materials" and encouraging their use has been one of the biggest challenges for the developers of green building rating systems. Prescriptive requirements such as transportation distance or rapid renewability too often fail to deliver the environmental performance that underlies the requirement. We would all welcome rules of thumb or labels to tell us which products are truly green, taking all factors into account over the whole life cycle. However, we can't get those answers without formal LCA or some equally thorough approach. In the absence of that kind of information, we should regard seemingly easy answers with caution. For example, the production and ultimate disposal of resins used in the manufacture of plastic wood have to be taken into account if that product is to be considered as one of the "better alternatives" to wood treated with chemicals, or to wood from old growth forests, as may be suggested in manufacturers' claims or well-meaning articles. Similarly, the environmental footprint of a product has more to do with the specifics of the manufacturing processes along the entire supply chain than with transportation distances to a construction site. And, in the case of transportation, the mode of transport is as relevant as a specific distance traveled.

Clearly we have to better integrate LCA techniques and LCA-based decision support tools in rating and certification systems, a goal that all of the system developers are working toward. But the application of LCA requires care that product comparisons are truly apple-to-apple comparisons. 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 a few 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 equal in the sense of true functional equivalence. In a similar vein, we have to be careful to account for all of 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.

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 preassembled components that can be compared to each other in terms of thermal performance or other criteria, without too much regard for broader systems implications.

The conundrum for rating system developers is how to introduce LCA with defined performance thresholds that must be met or exceeded, without requiring design teams to undertake yet another fairly complex type of simulation. GBI tackled that problem by commissioning a new software tool for use with Green Globes. The tool was created through a contract with Morrison Hershfield Consulting Engineers in association with the University of Minnesota's Center for Sustainable Building Research and the Athena Institute. Modeled on the Building Research Establishment's (BRE) Green Guide to Specification, which has been used in the U.K. for over a decade, it measures the global warming potential and other environmental impacts of hundreds of common building assemblies in low- and high-rise categories. Focusing on assemblies instead of individual products deals with the functional equivalence problem discussed above.

The new tool allows a comparison of material assemblies across environmental indicators such as embodied primary energy, which stands as a proxy for fossil fuel use, global warming potential, toxic releases to air, and toxic releases to water. Rather than combining disparate LCA impact measures using weighting and then attributing points to the combined total, Green Globes will attribute points to each assembly in each impact category. This approach serves a valuable educational function because it lets members of the design team more readily see where they're earning their points. The tool will be continually updated as new building product data and new assemblies emerge in the market. Manufacturers can contribute relevant data to the U.S. LCI Database Project (www.nrel.gov/lci).

The LCA tool has gone through the ANSI technical committee process from the perspective of its fit within the Green Globes system, including the assignment of points to that part of the resources assessment area and to the specific LCA measures. In addition, the resources subcommittee has been providing invaluable input with regard to the definition of assemblies and procedures to ensure that a level playing is maintained in the assembly comparisons and award of points under each measure.

Recognizing its importance as a "climate change calculator," the GBI has contributed its share of the intellectual property so that the Athena Institute can make a generic version of the tool freely available for use by other green building organizations, government entities, trade associations, and universities. Several regional versions of the generic tool have been developed, and more are in process, to better reflect life cycle impacts based on local conditions. In fact, one of these regional versions is already incorporated in the Minnesota Sustainable Building Guidelines.

I should note that this same approach was recommended for the U.S. Green Building Council's (USGBC's) LEED rating system in a report from the Goal and Scope Working Group of the "LCA into LEED" initiative that was launched in September 2004. The USGBC board has now endorsed that recommendation and work is underway to examine the specifics of how it might be best implemented from the USGBC's perspective.

Concluding Observations Regarding Rating Standards

An underlying implicit theme of this paper is the relative importance of design guidance versus rating objectives in building assessment and rating systems. There may be a natural tendency for organizations to focus more on the ratings side of the equation—often referred to as point hunting—at the expense of a continual effort to foster and facilitate increased performance. Perhaps it will turn out in the longer run that getting specific scores or ratings and achieving true performance are not fully compatible objectives, in which case we must surely question a continued emphasis on ratings and focus more on design guidance and performance requirements. Indeed, there may be a danger that an over-emphasis on ratings could stifle critical innovation: it is not recognized by the system, so best not to try it. At the same time, one can argue that ratings have a market value that attracts developers who might otherwise ignore sustainability criteria.

These kinds of issues have been central to much of the discussion within the Green Globes ANSI process. As well, the committees have focused a great deal of attention on the issue of minimum performance requirements, codes at various levels, and other standards that can or should be referenced in a rating system. One key related issue is the definition of "mainstream," given that Green Globes is focused on the mainstream commercial building market. The basic position that has been taken is that "mainstream" is not necessarily restricted to any given size, type, or cost of building or to any specific group of practitioners. Nor does the term refer to a specific level of building performance. Rather, mainstream refers to the vast majority of buildings and practitioners, as opposed to buildings that are being "showcased" for marketing, corporate image, demonstration, or other reasons. Any building type of any size can, and should, be expected to perform as designed and intended within a given budgetary constraint. The goal of green building is to go beyond that point and ensure that all buildings are designed for higher than average performance across a range of energy use, water use, air quality, and other environmental measures.

In keeping with this definition, Green Globes is designed to reach the mainstream by making the system as simple to use, nonbureaucratic and cost-effective as possible. Any building of any size should be able to reach exemplary levels of performance and, while achieving a third-party verified certification is highly desirable, a high performing building is the ultimate goal. To meet that objective, the system is designed to make its use as easy as possible for beginners as well as experienced practitioners. The task for the ANSI committee, and its subcommittees, is to maintain the integrity and performance expectations of the system without sacrificing the simplicity and cost advantages that it offers. The committee has therefore been careful to underscore the fact that appeal to the mainstream should not be interpreted as a reduction in performance expectations or requirements.

When it came to the question of minimum requirements or prerequisites, and the related issue of crediting performance that is essentially meeting codes, the committee generally agreed with the following principles.

1. Design teams should not be rewarded for simply meeting widely accepted codes and, further, such codes should not be used as prerequisites.
2. However, there are jurisdictional differences with regard to some codes and it might therefore be appropriate to credit meeting codes that require a higher level of performance and that have not been widely adopted.
3. The question of formal prerequisites or required minimum performance deserves continuing study, with one possibility being a requirement that design teams achieve a minimum number of points within each of the seven assessment areas.

Some of the above issues may eventually be superseded by the development of minimum high performance standards that can simply be cited and required within a rating system. The decision by ASTM E06-71 "Standard Specification for the Minimum Attributes of a Building that Promotes Sustainability," to define a minimum standard for high performance buildings is a good example, as is the work underway by an ASHRAE-led consortium. We see more emphasis elsewhere in the world on this approach, especially in terms of energy use and related greenhouse gas emissions. For example, energy performance certificates for buildings are being introduced throughout the Member States of the European Union as a result of the EU Energy Performance of Buildings Directive (EPBD). The objective of energy certification is to raise public awareness of energy use in buildings and to allow a comparison across similar building types. That directive is driving the development of processes, standards and tools in member states, with voluntarism fading as nonnegotiable requirements come to the fore. In North America, we still lean heavily toward the voluntary, market-driven approach. The question is—"how long we can hang on to that approach in the face of a looming global warming crisis?"

References

[1] Bordass, W., Cohen, R., and Field, J., “Energy Performance of Non-Domestic Buildings: Closing the Credibility Gap,” *Advanced Building News*, Nov. 2005.

[2] Turner, C., “LEED Building Performance in the Cascadia Region: A Post Occupancy Evaluation Report,” prepared for the Cascadia Region Green Building Council, Jan. 30, 2006.

Journal of ASTM International, Vol. 5, No. 2
Paper ID JAI101162
Available online at www.astm.org

Junko Endo,[1] *Shuzo Murakami,*[2] *and Toshiharu Ikaga*[2]

Designing a System to Apply an Assessment Method of Buildings for All Lifecycle Stages Based on the Concept of Eco-Efficiency

ABSTRACT: CASBEE (Comprehensive Assessment System for Building Environmental Efficiency) is an environmental labeling method for buildings, based on assessment of the environmental performance of buildings. In CASBEE, BEE (Building Environmental Efficiency) was developed as a new indicator for assessment following the concept of eco-efficiency. With the increasing BEE value, the total environmental performance of buildings is labeled from the highest performance. The framework of basic and extended CASBEE tools as a structured assessment system is called the "CASBEE family." CASBEE consists of a set of four basic assessment tools; namely, "CASBEE for Pre-design" (CASBEE-PD), "CASBEE for New Construction" (CASBEE-NC), "CASBEE for Existing Building" (CASBEE-EB), and "CASBEE for Renovation" (CASBEE-RN). These correspond to the individual stages of the building's lifecycle. There are also needs for detailed assessment targeting specific environmental aspects. "CASBEE-HI," as an extended tool, assesses efforts made in buildings to alleviate the heat island effect. A new tool called "CASBEE for Urban Development" (CASBEE-UD) is developed for assessment of a group of buildings. Some local authorities introduced CASBEE into their building administration as assessment methods for their sustainable building reporting systems. This requires building owners to submit a planning document assessing the environmental performance of their buildings to the authorities. In April 2004, the city of Nagoya introduced "CASBEE Nagoya." Introduction of CASBEE followed in the city of Osaka, Yokohama, Kyoto, and other municipals. These local systems require some modification in CASBEE to reflect their local characteristics, such as climate and prioritized policies.

KEYWORDS: building environmental assessment, environmental efficiency, environmental labeling, environmental policy, building administration, sustainable building reporting system, information disclosure

Introduction

After the increase in the consciousness of global environmental problems in the 1990s, a number of methods were developed for comprehensive assessment of building environmental performance, including BREEAM, LEED™, and GBTool. The development of the Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) was started in 2001 with the assistance of the Japanese Ministry of Land, Infrastructure and Transportation (MLIT). To date, a series of CASBEE tools has been elaborated and released for a wide range of building types. This paper presents the concept and framework of the assessment method and its application.

Eco-Labeling Based on the Concept of Eco-Efficiency

It is well known that Weizsacker, Schmidt-Bleek, and others are advocating concepts such as "Factor 4" and "Factor 10" to proceed with reform in the resource productivity of the developed countries, based on their conclusions that the sustainability of the earth's eco-system cannot be maintained without an increase by a factor of 4 or a factor of 10 in resource efficiency [1]. The principle of resource efficiency is expressed in the following formula:

Manuscript received March 26, 2007; revised January 1, 2008; accepted for publication January 17, 2008; published online February 2008.
[1] Senior Consultant, Center for Environment Energy Planning, Nikken Sekkei Research Institute, Daiichi Tekko Bldg. 5F, 1-8-2, Marunouchi, Chiyoda-ku, Tokyo 100-0005, Japan.
[2] Professor, Faculty of Science and Technology, Keio University, Dr. Eng., 3-14-1 Hiyoshi Kohoku-ku, Yokohama City, Kanagawa 223-8522, Japan.

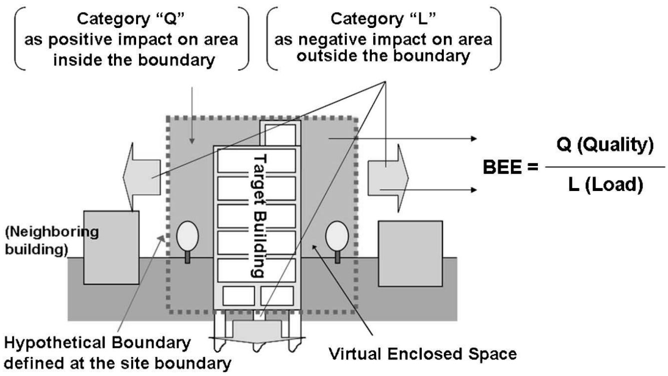


FIG. 1—*Definitions of Q, L, and BEE based on virtual enclosed space.*

$$\text{Resource Efficiency} = \frac{\text{Asset and Service Production}}{\text{Resource Input}}$$

An index similar to resource efficiency is utilized by organizations such as the WBCSD (World Business Council for Sustainable Development) and the OECD (Organization for Economic Cooperation and Development) based on the eco-efficiency approach. This is defined as follows:

$$\text{Eco-efficiency} = \frac{\text{Quality of Life}}{\text{Impact on the Environment}}$$

These approaches are attempts to coordinate and unify the various and different aspects involved in environmental assessment and express them in terms of efficiency. They are excellent approaches due to their remarkable clarity and the simplicity of the principles. CASBEE is the first attempt in the world to apply the eco-efficiency approach to this sort of system. Specifically, the eco-efficiency approach has been applied to issues of environmental assessment of buildings, producing an index of Building Environmental Efficiency (BEE), defined by the following equation:

$$\text{BEE} = \frac{\text{Q(Building Enviromental Quality)}}{\text{L(Building Environmental Load)}}$$

In order to define the terms Q and L used in the BEE definition, the new concept of hypothetical boundary at the site boundary is introduced as shown in Fig. 1. In Fig. 1, Category "Q" is assessed as the improvement of environmental quality within the virtual enclosed space. Category "L" is assessed as the negative impact on the environment outside the virtual enclosed space.

The method of labeling based on BEE is shown in Fig. 2. BEE values are represented on the graph by

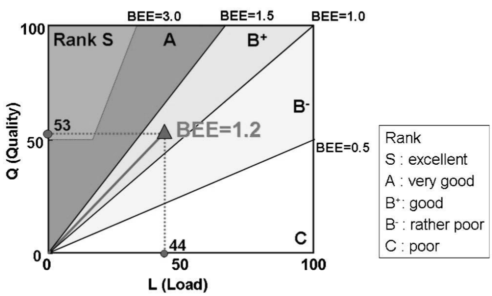


FIG. 2—*Environmental labeling of buildings utilizing BEE (example).*

plotting L on the x axis and Q on the y axis. The BEE value assessment result is expressed as the gradient of the straight line passing through the origin (0,0). Here the criteria for assessment items are decided so that the buildings on the diagonal line (BEE=1.0) are indicated as ordinary buildings. The higher the Q value and the lower the L value, the steeper the gradient, and the more sustainable the building is. With an increasing BEE value, total environmental performance of buildings is labeled as C rank (poor), B^-, B^+, A, or S (excellent). CASBEE is based on the eco-efficiency approach, and has an advantage over the many building assessment systems around the world due to this clear concept [2,3].

Basic Conditions for Developing CASBEE

Three Major Concepts for CASBEE

The development and extension of CASBEE is based on three major concepts. First, CASBEE is designed for assessment of buildings, which corresponds to their lifecycle. Second, it is based on the concept that clearly distinguishes environmental load (L) and quality of building performance (Q) as the major assessment targets. Thirdly, CASBEE applies the concept of eco-efficiency as BEE (Building Environmental Efficiency). Given L and Q, BEE is defined as Q/L to indicate the overall result of environmental assessment of buildings.

The Basic Approach to CASBEE Development

CASBEE has been developed in accordance with the following principles:

(1) It should be a positive assessment tool for designs with superior environmental consideration, rather than simply a negative checklist, in order to motivate designers, clients, and others to be more interested in using the tool.
(2) The assessment system should be kept as simple and comprehensible as possible.
(3) It should be a general-purpose tool, able to evaluate buildings with wide-ranging types and sizes. To ensure widespread use, it should have a flexible structure enabling to reflect innovative initiatives taken by users based on their organizational circumstances.
(4) It should take into consideration issues and problems particular to Asia and Japan.

Applications of CASBEE

CASBEE is intended to serve applications for both public use and private use. It can be described according to the three major uses of CASBEE.

Application in the Public Sector

(1) Application to building administration: Some local authorities introduced CASBEE into their building administration as assessment methods for their sustainable building reporting systems. This requires building owners to submit a planning document assessing the environmental performance of their buildings to the authorities. In April 2004, the city of Nagoya introduced “CASBEE Nagoya.” Introduction of CASBEE followed in the cities of Osaka, Yokohama, Kyoto, and other municipalities. Detail is described in the section “Administrative Use of CASBEE.”
(2) Use in selection of design competition proposals, and of private finance initiative (PFI) project operators: It is anticipated that CASBEE will be used for grading design competition proposals, selecting PFI project operators and checking environmental performance of buildings at the design stage. The CASBEE rating can also be used between building clients and designer, or between owners and occupants, to determine environmental targets.
(3) Certification by a third party: The CASBEE rating is now subjected to third-party certification. A training program is also available to become an accredited assessor for CASBEE. Public use of CASBEE demands a higher level of fairness and confidence in the assessment results. Those systems are expected to become popular, although assessment by CASBEE is primarily a voluntary activity.

TABLE 1—*CASBEE's four basic assessment tools.*

Names	Abbreviation	Tool No.	Development schedule
CASBEE for Pre-design	CASBEE-PD	Tool-0	Not completed
CASBEE for New Construction	CASBEE-NC	Tool-1	Completed in July 2003
CASBEE for Existing Building	CASBEE-EB	Tool-2	Completed in July 2004
CASBEE for Renovation	CASBEE-RN	Tool-3	Completed in March 2005

Application in Businesses

(1) For designers to employ design for the environment (DfE): CASBEE can serve as an assessment tool that designers can use to check the environmental performance of buildings at the design stage by themselves, and provide their clients and others with objective information on environmental considerations.

(2) Environmental labeling that can be used in the asset valuation of buildings: Environmental labeling of buildings is also possible through certification by a third party, when buildings are valued as assets. Organizations can improve their corporate image through such labeling activities for the environment. Furthermore, CASBEE can be used as a tool to generate proposals for building operation monitoring, commissioning, and upgrade design with a view to ESCO (Energy Service Company) projects and building stock refurbishment. CASBEE has the potential to be utilized in several stock management situations.

Application in Education

For specialized education, such as university and college courses of architecture, CASBEE can be used as a teaching resource. It is also useful as training material for professional continuing professional development (CPD) programs.

Framework of CASBEE: The CASBEE Family

Building Lifecycle and the CASBEE Family

CASBEE consists of a set of four basic assessment tools including "CASBEE for Pre-design" (CASBEE-PD), "CASBEE for New Construction" (CASBEE-NC), "CASBEE for Existing Buildings" (CASBEE-EB), and "CASBEE for Renovation" (CASBEE-RN), which correspond to the individual stages of a building's lifecycle as shown in Table 1. These tools can be applied for many types of buildings, such as offices, schools, retail stores, restaurants, halls, hospitals, hotels, and apartments. These tools are basically designed to assess single buildings.

"CASBEE Family" is the collective name for these four tools and the extended tools for specific purposes. Figure 3 presents the relationship between these tools and the corresponding lifecycle of buildings. Figure 4 shows the scope of the CASBEE Family.

Outline of the Basic Assessment Tools

CASBEE for Pre-Design (CASBEE-PD)—This tool aims to assist the owner, planner, and others involved in the planning (pre-design) stage of the project. It can be used to assist in grasping issues such as the basic environmental impact of the project, in selecting a suitable site, and to evaluate the environmental performance of the project in the pre-design stage.

CASBEE for New Construction (CASBEE-NC)—This is used by architects and engineers to increase the BEE value of a building during the design process [4]. This can be used as a design support tool as well as a self-checklist. This tool, formerly named DfE (Design for Environment) tool, makes assessments based on the design specifications and the anticipated performances. Rebuilding projects are assessed by CASBEE-NC. At the Preliminary Design, Execution Design, and Construction Completion phases, the environmental quality and performance of the building and its load reduction performance are evaluated. As environmental performance and assessment criteria change over time, the results of assessments under

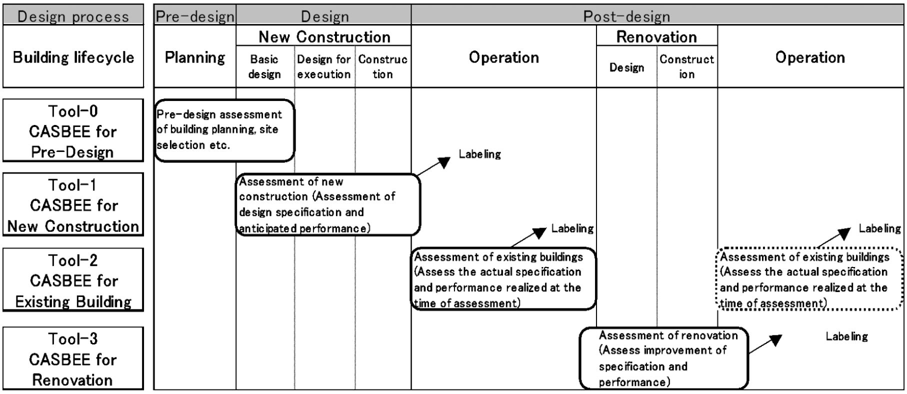


FIG. 3—*Building lifecycle and the four assessment tools.*

"CASBEE for New Construction" only remain valid for three years after the completion of construction. Figure 5 illustrates the assessment results of new building projects in Nagoya City using CASBEE-Nagoya, which is customized to Nagoya City by considering the specific conditions in this city.

CASBEE for Existing Building (CASBEE-EB)—This assessment tool targets existing building stock, based on operation records for at least one year after completion [5]. The tool is also developed to be

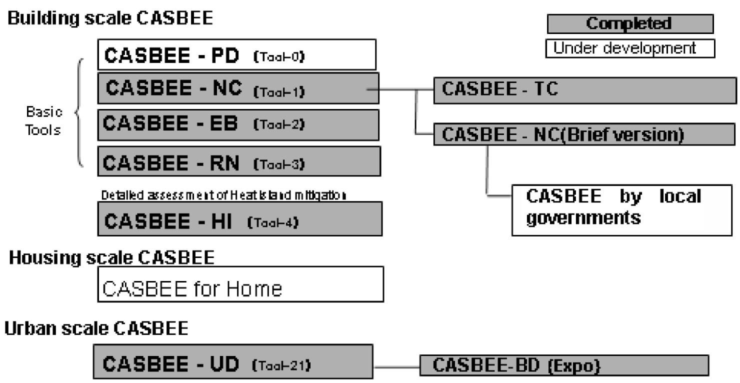


FIG. 4—*Scope of CASBEE family.*

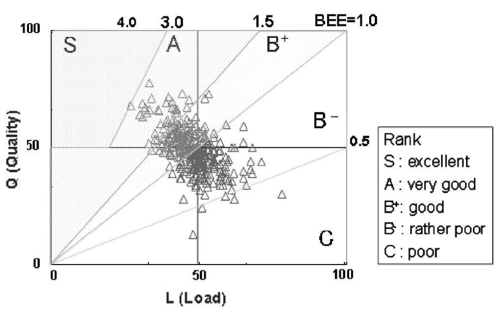


FIG. 5—*Assessment results of new building projects in Nagoya City using CASBEE-Nagoya.*

TABLE 2—*Assessment results of sample office buildings evaluated by CASBEE-EB (version year 2006).*

CASE	Building type	Year of completion	BEE	Q	L	Rating
A	Office	1999	3.7	84	23	S
B	Office	2002	2.5	71	28	A
C	Office	2003	3.0	75	25	S
D	Office	1960	1.4	61	43	B^+
E	Office	2002	3.0	73	24	S
F	Office	2003	3.0	66	22	S
G	Office	1996	2.9	79	26	A
H	Office	1979	1.8	59	32	A
I	Office	1992	1.8	64	35	A
J	Office	1998	1.7	68	39	A
K	Office	2002	2.8	73	26	A

applicable to asset assessment. This assessment tool evaluates achieved performance or installation when the assessment is made. The result is valid for five years, and requires revision using the latest version of the assessment tool, because the condition of the building may change over time.

It can be used as a labeling tool to declare the environmental performance of buildings. CASBEE-EB is also utilized to support building maintenance. Building owners, such as the real estate sector and large enterprises, may use it as a self-evaluation tool for mid-term and long-term management plans.

Some assessment examples by CASBEE-EB (version year 2006) are shown in Table 2. These buildings are offices built between in 1960 and 2003. Figure 6 shows the distribution of these results, indicating that most buildings showed good results. It may be because most of the buildings in Fig. 6 were built within the last five years.

CASBEE for Renovation (CASBEE-RN)—CASBEE-RN is designed to evaluate the performances of existing buildings based on predicted performance and specifications with renovation [6]. It can be used for building-stock renovation, and to generate proposals for building-operation monitoring, commissioning, and upgrade design with a view to ESCO projects. It is valid for three years after completion of the renovation work, and assessment must be made with the latest version of CASBEE-RN at the point of assessment. This tool can be used to evaluate the degree of improvement (increased BEE), relative to the level that preceded renovation. An example of CASBEE-RN's result (version year 2006) is presented in Fig. 7.

CASBEE-RN may also assess improvement of specific performance in relation to the purpose of the renovation. For instance, the BEE for energy saving can be presented, which is determined by the scores for assessment categories especially related to energy saving renovation, such as Energy (LR-1) and Indoor environment (Q-1).

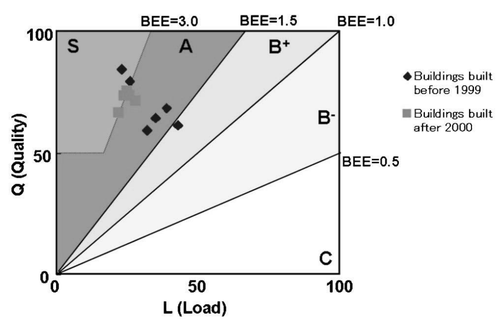


FIG. 6—*CASBEE-EB Assessment results for sample offices (version year 2006).*

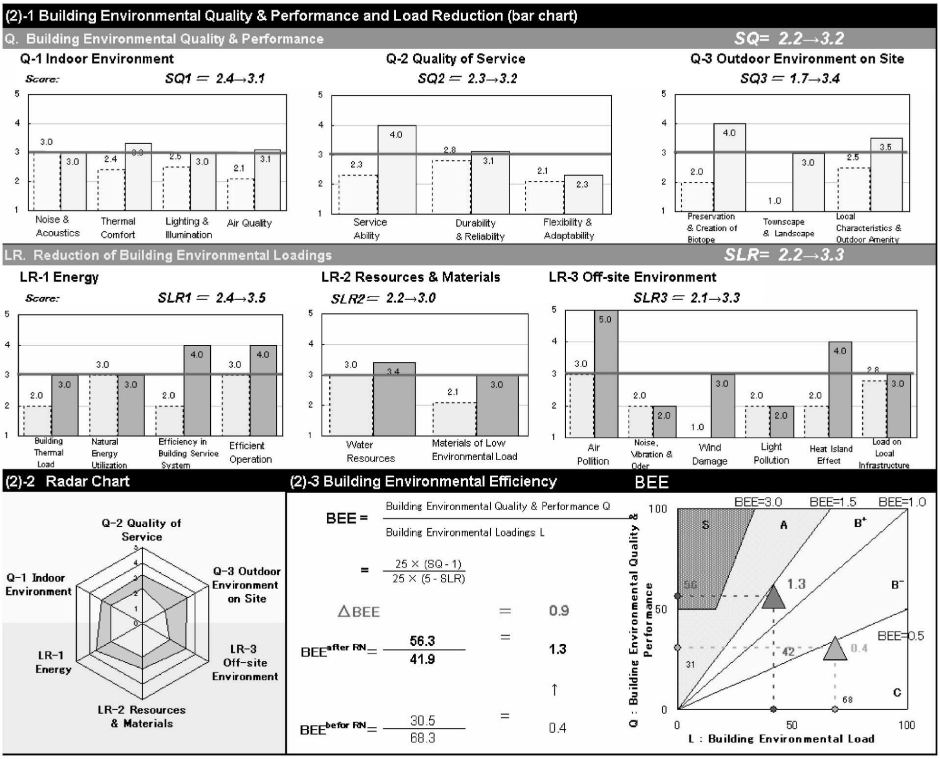


FIG. 7—*Example of assessment result by CASBEE-RN (version year 2006): comparison between before and after renovation.*

Extended Tools of CASBEE

The basic CASBEE tool suite is applicable to a diverse range of individual applications. Several extended tools have been developed as shown in Table 3.

CASBEE for Temporary Construction—The tool called "CASBEE for Temporary Construction" (CASBEE-TC) was developed as an extension to CASBEE for New Construction for evaluating temporary buildings constructed specifically for short-term use, such as Expo pavilions. Buildings of this type have short-term lifecycles, and therefore consideration must concentrate largely on material use and recycling in the construction and the demolition phases. The scoring criteria and weighting reflect the features of this type of buildings. So far, the tool has been completed in a version limited to exhibition facilities [7].

CASBEE for New Construction (Brief Version)—Assessment using CASBEE for New Construction may take 3–7 days, including the time required to prepare documents necessary as the basis for scoring. "CASBEE for New Construction (Brief version)" was developed to meet the growing need for a tool to handle objectives such as a simplified setting of the Building Environmental Efficiency level and preparation of documents for submission to government agencies. It makes a simplified, provisional assessment possible in around 2 h (excluding time for the preparation of an Energy Saving Plan) [8].

Application of CASBEE by Local Governments—CASBEE is used by local authorities in construction administration; namely, sustainable building reporting systems. They can tailor CASBEE for New Construction (Brief version) to local conditions, such as climate and prioritized policies. Examples are "CASBEE Nagoya," "CASBEE Osaka," and "CASBEE Yokohama."

TABLE 3—*Extended CASBEE tools for specific purposes (as of January 2007).*

Title	Application	Outline
CASBEE for Temporary Construction	Temporary construction	Currently adapted to exhibition facilities.
CASBEE for New Construction (Brief version)	Simple preliminary assessment	Simplified edition of CASBEE for New Construction.
Localized CASBEE	For individual local areas	CASBEE for New Construction (Brief version), tailored to regional characteristics
CASBEE-HI	Assessment on the efforts in alleviating the heat island phenomenon	Detailed assessment of the heat island effect using CASBEE
CASBEE for Home	Houses	Pilot version is released for Detached House
CASBEE for Urban Development	Urban scale development	Assessment of groups of buildings for urban scale development

CASBEE-HI—Assessment of the heat island effect is essential in major urban areas, such as Tokyo and Osaka. CASBEE for heat island alleviation (CASBEE-HI) is a tool aiming for more detailed quantitative assessment of heat island relaxation measures in building design [9]. In CASBEE-HI, the criteria deal with more detailed conditions in the outdoor thermal environment and the heat island load to surroundings. (These are also addressed in CASBEE-NC.) CASBEE-HI is also evaluated with the concept of eco-efficiency. BEE_{HI} (Building Environmental Efficiency for Heat Island Relaxation), indicating efficiency in measures taken to reduce the heat island effect, as in the following equation:

$$BEE_{HI} = \frac{Q_{HI}}{L_{HI}} = \frac{\text{Improvement of thermal environment inside the virtual boundary}}{\text{Heat island load outside the virtual boundary}}$$

CASBEE for Home—The four basic tools are not applied to detached houses, although they are applied to apartments. CASBEE for Home is being developed for detached houses. A pilot version was released in July 2006 [10].

CASBEE for Urban Development—"CASBEE for Urban Development" is applied to projects including multiple buildings [11]. This tool considers the human efforts and effects of a group of buildings, other than those of single buildings, which improve the environmental performance of the urban area as a whole. As a specialized tool, "CASBEE for District Neighborhoods (Expo) version March 2005" has been completed and was used to assess the site plan of the World Expo 2005 Aichi, Japan.

Administrative Use of CASBEE

In recent years, many major cities in Japan have adopted "sustainable building reporting systems" as an environmental policy in their building administration. To operate this system, these local authorities utilize an environmental performance evaluation method for buildings as policy instruments. The system appear to have become a very strong driving force in spreading environmental measures in building construction, and consequently environmental performance assessments of buildings are carried out in many buildings.

Outline of Sustainable Building Reporting Systems

Local governments are enthusiastic in adopting environmental performance assessment for their building administration in Japan. Table 4 shows local authorities that have adopted sustainable building reporting systems. Under required ordinances and guidelines, building owners are asked to carry out comprehensive assessment of their buildings' environmental performance when a building above a certain size is newly

TABLE 4—*Administrative use of environmental performance assessment tool for buildings by local governments.*

Municipality[a]	Started	Subject building
Tokyo Metropolitan Government[b]	2002.06	New construction over 10 000 m^2 total floor area
Nagoya City	2004.04	New construction or extension over 2000 m^2 total floor area
Osaka city	2004.10	New construction over 5000 m^2 total floor area or New construction applied for extra maximum floor-area ratio more than 1000 m^2 site area
Yokohama city	2005.07	New construction or extension over 5000 m^2 total floor area
Kyoto city	2005.10	New construction or extension more than 2000 m^2 total floor area
Kyoto prefecture	2006.04	New construction or extension more than 2000 m^2 total floor area
Osaka prefecture	2006.04	New construction or extension over 5000 m^2 total floor area
Kobe city	2006.08	New construction or extension more than 5000 m^2 total floor area or New construction applied for extra floor-area ratio more than 2000 m^2 total floor area
Kawasaki city	2006.10	New construction or extension over 5000 m^2 total floor area
Hyogo prefecture	2006.10	New construction or extension more than 5000 m^2 total floor area

[a]Shizuoka prefecture, Fukuoka City, Sapporo City, and Kitakyushu City will also introduce CASBEE.
[b]The system does not use CASBEE as an assessment tool.

constructed. These results must be reported to the authority and the authority must publish the submitted assessment results of environmental performance. Most authorities use the Internet to disclose the results and the summary of environmental measures taken by the building owners to improve environmental performance.

The system is designed to promote voluntary actions by building owners for the environment through information disclosure to the local residents, by showing which building owners are active in environmental measures.

Localized CASBEE for Sustainable Building Reporting Systems by Local Governments

Now, CASBEE has been developed to a level where it is applicable to new buildings. "CASBEE for New Construction (Brief version)" have been developed to meet the growing need for a simpler version of CASBEE-NC that saves time for document preparation. CASBEE-NC (Brief version) is now widely used by the sustainable building reporting systems.

On the other hand, CASBEE is also intended to take regional conditions into consideration as background for the assessment. Local characteristics such as infrastructure, local economy, climate, and history may vary. Local authorities that use this tool can tailor it to local conditions, such as climate and prioritized policies. Changes are generally made by modifying the weighting coefficients. Flexible response to regional character is a common feature of all elements of CASBEE. One example is "CASBEE-Nagoya." CASBEE-Nagoya has its own scoring guidelines that instruct some criteria in relation to local contexts, such as materials from local industry, and that define some excluding criteria [12]. Another example is CASBEE-Osaka, which altered coefficient weights from the original to reflect the high priority they give to the heat island policy. The city of Osaka started administrative use of CASBEE from October, 2004, changing the weights of Q-1 Indoor environment from 0.4 to 0.3 and Q-3 Outdoor environment on site from 0.3 to 0.4 [13].

Advanced Application of CASBEE to Promote Sustainable Buildings in the Building Markets

Further, it is possible to provide incentives to buildings that achieve high ratings with CASBEE. CASBEE Osaka applies to buildings over 5000 m^2 of total floor space, or buildings of over 1000 m^2 of site area.

These buildings cover approximately 40 % of total floor area of annual new construction in Osaka city. In Osaka city, the rating should at least reach the B+ class, the third of CASBEE's five grades, if the approval for an administrative scheme, called "sougou sekkei seido," is given to the building being assessed (Osaka City, 2004) [13]. The maximum floor-area ratio of the building can be increased in this scheme. The city is the first municipality to make rating by CASBEE Osaka a condition in qualifying for the scheme.

Financial support can be provided for high score buildings assessed by CASBEE. The city of Osaka subsidizes residential buildings that are A-ranked by CASBEE. The city of Nagoya also subsidizes the residential buildings selected in order of BEE value by CASBEE. In Kawasaki city, developers who are selling multi-residential units must publish CASBEE results in their advertisements to inform consumers about the environmental performance of the buildings [14]. The financial sector, such as banks, may utilize such information to offer better interest rates to the consumers who buy environmentally high performance residential units [14].

Summary

CASBEE is intended to serve various applications for both public use and private use; namely, application for public policies, business, and education. Local governments seem to be the most active in introducing CASBEE for practical use. The scope of CASBEE is summarized as below.

(1) CASBEE consists of a set of four basic assessment tools: "CASBEE for Pre-design," "CASBEE for New Construction," "CASBEE for Existing Building," and "CASBEE for Renovation." They correspond to the individual stages of the building's lifecycle.
(2) In CASBEE, BEE (Building Environmental Efficiency) was developed as a new indicator for assessment following the concept of eco-efficiency.
(3) "CASBEE Family" is the collective name for CASBEE's four basic assessment tools and the extended tools for specific purposes.
(4) Some extended tools for specific purposes have been developed, such as CASBEE for Temporary Construction (exhibition facilities), CASBEE for New Construction (Brief version), and its variations reflecting local conditions, CASBEE-HI.
(5) "CASBEE for Urban Development" broadened assessment to cover efforts applied to areas including multiple buildings.
(6) CASBEE Nagoya and CASBEE Osaka were first enacted in 2004 as tools for the sustainable building reporting systems. They also incorporated local context into their systems. Incentives are provided to buildings which gain high ratings with CASBEE.

Acknowledgments

The authors express sincere thanks to the Committee members of the Comprehensive Assessment System of Building Environmental Efficiency, the Housing Bureau of the Japanese Ministry of Land, Infrastructure and Transportation for its extensive support for this study.

References

[1] Schmidt-Bleek, F., *Wieviel Umwelt braucht der Mensch? MIPS—das Mab fur okologisches Wirtschaften*, Birkhauser, Basel/Berlin, 1994.
[2] Murakami, S., Sakamoto, Y., Yashiro, T., Iwamura, K., Bogaki, K., Oka, T., Sato, M., Ikaga, T., and Endo, J., "Comprehensive Assessment System for Building Environmental Efficiency in Japan (CASBEE-J)," *Proceedings of Sustainable Building 2002 International Conference*, Oslo, 2002.
[3] Ikaga, T. "CASBEE: New Labeling System Based on Environmental Efficiency," *Proceedings of 6th Int. Conf. on EcoBalance*, Tsukuba, 2004, pp. 249–252.
[4] Japan Sustainable Building Consortium, *CASBEE Technical Manual 2006 Edition: CASBEE for New Construction*, Institute for Building Environment and Energy Conservation, Tokyo, 2006.
[5] Japan Sustainable Building Consortium, *CASBEE Technical Manual 2006 Edition: CASBEE for*

Existing Building, Institute for Building Environment and Energy Conservation, Tokyo, 2006 (in Japanese).

[6] Japan Sustainable Building Consortium, *CASBEE Technical Manual 2006 Edition: CASBEE for Renovation*, Institute for Building Environment and Energy Conservation, Tokyo, 2006 (in Japanese).

[7] Japan Sustainable Building Consortium, *CASBEE Technical Manual 2005 Edition: CASBEE for Temporary Construction (for exhibition facilities)*, Institute for Building Environment and Energy Conservation, Tokyo, 2005 (in Japanese).

[8] Japan Sustainable Building Consortium, *CASBEE Technical Manual 2006 Edition: CASBEE for New Construction (Brief version)*, Institute for Building Environment and Energy Conservation, Tokyo, 2006 (in Japanese).

[9] Japan Sustainable Building Consortium, *CASBEE Technical Manual 2006 Edition: CASBEE-HI*, Institute for Building Environment and Energy Conservation, Tokyo, 2006 (in Japanese).

[10] Japan Sustainable Building Consortium, *CASBEE Technical Manual 2006 Edition: CASBEE for Home (Pilot version)*, Institute for Building Environment and Energy Conservation, Tokyo, 2006 (in Japanese).

[11] Japan Sustainable Building Consortium, *CASBEE Technical Manual 2006 Edition: CASBEE for Urban Development*, Institute for Building Environment and Energy Conservation, Tokyo, 2006 (in Japanese).

[12] Noda, H. "City of Nagoya's Sustainable Building System Characterized by Environmental Efficiency Evaluations and its Official Announcements," *Proceedings of 6th Int. Conf. on EcoBalance*, Tsukuba, 2004, pp. 253–254.

[13] City of Osaka website; http://www.city.osaka.jp/jutaku/sido/casbee10.html

[14] Kawasaki city website; http://www.city.kawasaki.jp/30/30kansin/home/casbee/casbee.htm

Journal of ASTM International, Vol. 5, No. 6
Paper ID JAI101163
Available online at www.astm.org

K. Steele[1] *and J. Anderson*[1]

BRE Environmental Profiles: Past, Present, and Future

ABSTRACT: Environmental conservation and the impact that the construction industry has on the environment have risen to the fore as a principle against which materials, products, specifications, and whole building fabric must be considered. The reasoning for this is sound, with the industry being responsible for the manufacture and use of hundreds of millions of tons of materials annually. At a national level in the UK alone the construction products sector is responsible for around 10 % [DEFRA statistics, 2000] of all carbon emissions. Against this background, the sector is remarkably well placed to build from work already done to develop standardized Life Cycle Assessment (LCA) approaches and to apply them to construction scenarios. As a result, the practice is now well established and has gained a growing momentum across all construction stakeholders, from clients to product suppliers.This paper examines BRE's experience in the field having originally developed an LCA approach called the "Environmental Profiles methodology" and used it to create an information database, specification tools, and a proprietary product certification scheme. The next phase of development is critical to the continuing success of these programs.

KEYWORDS: environmental profiles, EPDs, building assessment, LCA

Introduction

In 1999, BRE completed a three year collaboration project with the construction materials sector, funded by the UK government, to develop a single, "level playing field" methodology, known as Environmental Profiles [1], for conducting life cycle assessments for building materials and components. Alongside the development of the methodology, BRE obtained generic LCA data for most key building materials from UK trade associations, leading to the production of publications and tools, such as *The Green Guide to Specification* [2] and ENVEST [3]. These enable designers and specifiers to make informed choices about buildings and materials on the basis of consistent life cycle based environmental information. The linkage between the Environmental Profiles method and industry tools can be seen in Fig. 1.

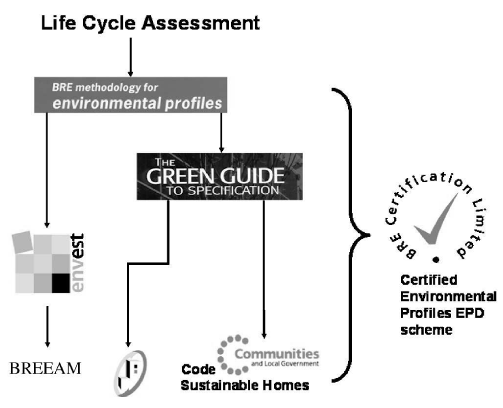
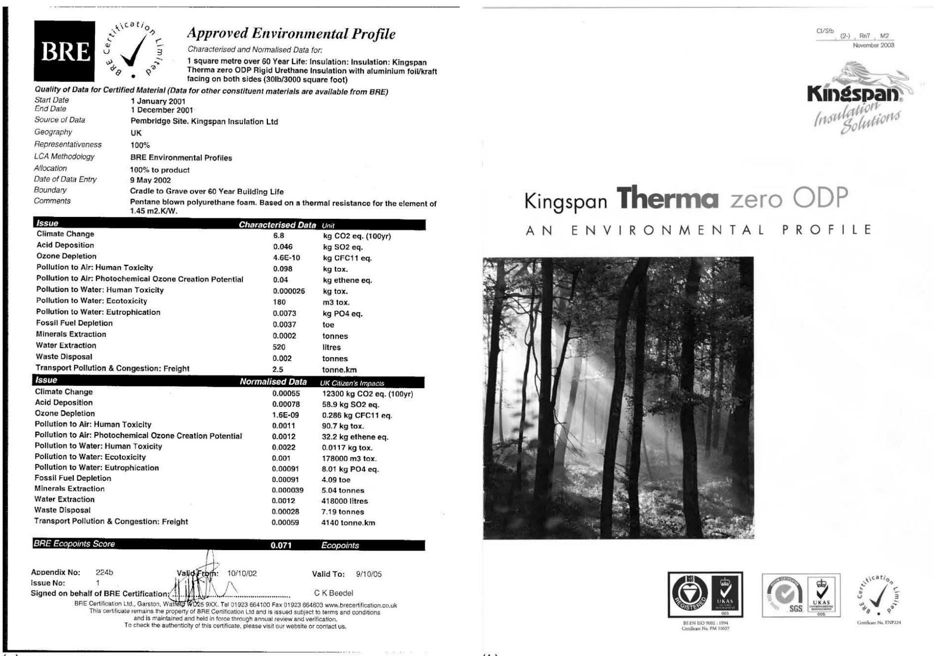


FIG. 1—*The UK context for using LCA to report the embodied impact of materials in the whole building assessment schemes.*

Manuscript received April 1, 2007; accepted for publication April 30, 2008; published online June 2008.
[1] BRE, Watford, United Kingdom.



BRE

BRE Certification Limited

Approved Environmental Profile

Characterised and Normalised Data for:

1 square metre over 60 Year Life: Insulation: Insulation: Kingspan Therma zero ODP Rigid Urethane Insulation with aluminium foil/kraft facing on both sides (30lb/3000 square foot)

Quality of Data for Certified Material (Data for other constituent materials are available from BRE)

Start Date	1 January 2001
End Date	1 December 2001
Source of Data	Pembridge Site. Kingspan Insulation Ltd
Geography	UK
Representativeness	100%
LCA Methodology	BRE Environmental Profiles
Allocation	100% to product
Date of Data Entry	9 May 2002
Boundary	Cradle to Grave over 60 Year Building Life
Comments	Pentane blown polyurethane foam. Based on a thermal resistance for the element of 1.45 m2.K/W.

Issue	Characterised Data	Unit
Climate Change	6.8	kg CO2 eq. (100yr)
Acid Deposition	0.046	kg SO2 eq.
Ozone Depletion	4.6E-10	kg CFC11 eq.
Pollution to Air: Human Toxicity	0.098	kg tox.
Pollution to Air: Photochemical Ozone Creation Potential	0.04	kg ethene eq.
Pollution to Water: Human Toxicity	0.000026	kg tox.
Pollution to Water: Ecotoxicity	180	m3 tox.
Pollution to Water: Eutrophication	0.0073	kg PO4 eq.
Fossil Fuel Depletion	0.0037	toe
Minerals Extraction	0.0002	tonnes
Water Extraction	520	litres
Waste Disposal	0.002	tonnes
Transport Pollution & Congestion: Freight	2.5	tonne.km

Issue	Normalised Data	UK Citizen's Impacts
Climate Change	0.00055	12300 kg CO2 eq. (100yr)
Acid Deposition	0.00078	58.9 kg SO2 eq.
Ozone Depletion	1.6E-09	0.286 kg CFC11 eq.
Pollution to Air: Human Toxicity	0.0011	90.7 kg tox.
Pollution to Air: Photochemical Ozone Creation Potential	0.0012	32.2 kg ethene eq.
Pollution to Water: Human Toxicity	0.0022	0.0117 kg tox.
Pollution to Water: Ecotoxicity	0.001	178000 m3 tox.
Pollution to Water: Eutrophication	0.00091	8.01 kg PO4 eq.
Fossil Fuel Depletion	0.00091	4.09 toe
Minerals Extraction	0.000039	5.04 tonnes
Water Extraction	0.0012	418000 litres
Waste Disposal	0.00028	7.19 tonnes
Transport Pollution & Congestion: Freight	0.00059	4140 tonne.km
BRE Ecopoints Score	0.071	Ecopoints

Appendix No: 224b Valid From: 10/10/02 Valid To: 9/10/05

Issue No: 1

Signed on behalf of BRE Certification: .... C K Beedel

BRE Certification Ltd., Garston, Watford WD25 9XX. Tel 01923 664100 Fax 01923 664603 www.brecertification.co.uk
This certificate remains the property of BRE Certification Ltd and is issued subject to terms and conditions and is maintained and held in force through annual review and verification.
To check the authenticity of this certificate, please visit our website or contact us.

(*a*)

(*b*)

FIG. 2—*(a) Approved Environmental Profile for Kingspan Therma Zero ODP. (b) Certified company report for Kingspan Therma Zero ODP.*

UK Context

In the UK material embodied impact comparison is done by using *The Green Guide to Specification* as part of whole building assessment schemes such as BRE Environmental Assessment Method (BREEAM) and EcoHomes [4]. These methods are on the verge of moving into the main stream with the establishment of the Code for Sustainable Homes (CSH). The Code is owned and operated by UK government through its Department of Communities and Local Government (CLG). Its establishment signifies a shift in the status of these whole building assessment schemes from voluntary to quasi-mandatory.

Despite these drivers, barriers to the creation and use of Environmental Product Declarations (EPDs) continue to exist. Practitioner experience, data quality, and cost represent three main problems slowing progress in the UK. All must be addressed if the future success of the UK schemes is to be assured.

Environmental Profiles Methodology: The UK Industry PCR

Environmental Profiles is an EPD scheme conceived for the UK construction industry in the 1990s and launched in 1999. The scheme was developed in collaboration with the UK materials industry and government and provides a single life cycle assessment methodology for the evaluation of construction materials, elements and buildings. Application of the methodology at any level will produce an EPD commonly called an "Environmental Profile." BRE and industry have produced Environmental Profiles for most key building materials used in the UK. This data have been produced in the main by working with industry trade associations.

In 2001, BRE Certification [5] established the Environmental Profiles Certification scheme through which EPDs for proprietary construction products could be assessed and reported. Working directly with material manufacturers, the scheme assesses company operations for product manufacture through a careful audit and review of production practice. It then assists the company to report findings through the published EPD (see Figs. 2(*a*) and 2(*b*)). The strength of the scheme is that it enables benchmarking and the ability for manufacturers to consider the performance of their operations against competitors and industry average data. The background generic perspective is reported in *The Green Guide to Specification*.

The Green Guide to Specification

The Green Guides to Specification are the major route through which construction materials LCA data are communicated to architects and building professionals. A guide for housing was published in 2000, and for commercial buildings in 2002. The guides are the most widely used tool in the UK for understanding the environmental implications of material choice and specification and over 8000 copies have been sold.

In recent years, the guides have been increasingly out of date. This has transpired as UK regulation has improved and building U values, which are used as the basis for many of the functional units within *The Green Guides*, have become more demanding. This, coupled with developments in LCA methodology, changes in technology in both the manufacturing and constructing industry, as well as in construction product material make-up, meant that by 2005, it was clear the guides required an update.

Updating Environmental Profiles

In 2005, BRE embarked on a development project with the aims of:

- updating the Environmental Profiles methodology;
- gathering a new platform of industry LCA data; and
- producing the next generation of *Green Guide* publication

The changes

Despite the project being evolutionary the scope of work has been extensive. The Environmental Profiles methodology has been significantly updated with the following major changes:

- use of national energy mixes for electricity production;
- clarification on value allocation in modeling recycling and waste treatment;
- use of treatment and disposal EPDs for sewer and solid waste streams;
- development of a data quality index with adjustments for low quality LCA data;
- update of characterization categories including selected use of the most recent CML impact methods, update of fossil fuel depletion, water consumption and minerals extraction models, and the establishment of a high level radioactive waste impact category;
- new normalization factors with an EU focus;
- design and delivery of a new weightings exercise that used an expert panel; and
- a new reporting format for the Environmental Profiles as EPDs

The 2007 Environmental Profiles methodology has been designed to be compliant to ISO14040, 14044, 14025, and 1930 and is currently going through a third party review process.

There has been huge interest in the project from the UK construction products sector. As such, BRE, with industry partners, has spent significant time gathering and updating LCA materials data. Industry engagement has been comprehensive with over 50 trade associations and more than 40 projects gathering information from hundreds of sites. The research program has developed the most complete database of construction product LCA data in the UK. Because it is founded on a single, consistent, and unbiased approach, the work provides a firm foundation from which to develop guidance.

The new *Green Guide* will be comprehensive and will include specifications from domestic, commercial, retail, health, education, and industrial building sectors. It will include information on all main building elements with over 15 elemental categories. The specification listing will grow from about 250 specifications to over 800. Publication will also herald the placement of data on the internet with the benefits of increased flexibility and accessibility. Moving to the internet will enable: the development of a calculator tool for users to construct and rate their own building elements; placement of proprietary data from the Environmental Profiles Certification Scheme; regular update and management of the specification archive; and the ability for the user to dig more deeply into the EPD system examining individual EPDs and ratings.

Change-Over

One of the largest problems faced by BRE has been how to handle the change-over of methodology. Manufacturers providing new data to update the original 1999 work are keen to see whether they have improved.

To do this, either the original data must be assessed using the new methodology, or the new data must be assessed to the original methodology. If it were just a case of changing the assessment methodology then this might be a simple task—however, because other aspects of the methodology have changed, it is more complex. Manufacturers are also keen to market environmental information and thus require some guarantee that data will be valid for a given period. BRE is therefore intending that it will switch to the new methodology for all work from 2007, with studies currently underway undertaken to both methodologies.

Methodological Changes

The biggest challenge will be if the new methodology significantly alters the current guidance provided by The *Green Guide*. If this occurs then adequate justification for the changes will have to be provided to our stakeholders.

Consultation and Dialog

Consultation with the construction materials industry and stakeholders of the system was an ongoing imperative from the outset.

A comprehensive process was put in place to ensure all stakeholders remained informed and consulted at all stages of the update. BRE has instituted a governance structure and procedures to cover both The *Green Guide* update and other projects such as BREEAM management. This involves a Sustainability Board who oversee key decisions, and expert panels who are involved with particular issues such as methodology development.

The Construction Products Association, the UK trade association which represents the majority of the construction products manufacturers, has been very involved in this process, with representatives sitting on both the Sustainability Board and the LCA methodology panel. Individual manufacturing sectors have also been very involved in the consultation process, and a wide variety of views have been expressed, with sectors often in direct opposition to BRE or to each other. Documents describing the consultation process, all the views expressed, and the final resolution have been published by BRE at their website (www.bre.co.uk/greenguide and follow links to update).

The process, although lengthy, has been a success. For a methodology to work it must have industry buy-in. Involvement through consultation, debate, and resolution has facilitated buy-in. The outcome is an updated LCA methodology that is clear, transparent, and built on a process of consensus. It provides a level playing field approach for the application of LCA to the construction sector.

Future Strategy

As ISO [6] and CEN [7] standardization is formalized, it is important that the BRE approaches are compliant ensuring their prevalence in Europe and beyond. This necessitates the update of the methodology and certification programs but also in ways in which information is presented on Environmental Profile certificates as formalized in the proprietary certification program.

Development work does not, however, stop here. The future holds plenty of opportunity and scope for broadening LCA application and involvement. Figure 3 provides a schematic of the current scheme and the interrelationship between the different outcomes.

Widening Access and Participation

BRE is working on strategic plans to put the Environmental Profiles methodology and database on a more accessible and transparent footing. This will pave the way for licensed access, opening up a market for the creation and publication of EPDs.

Quality management of Life Cycle Inventory data and the correct application of methodology is

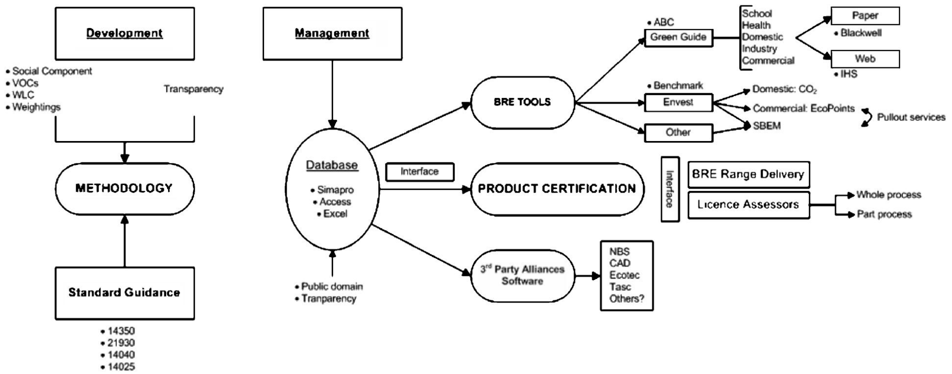


FIG. 3—*The relationship between the Environmental Profiles methodology, its support database, and the scheme and industry tools that have been developed from it.*

important. This will be controlled through licensing trained LCA practitioners and organizations to undertake proprietary product EPD Certification. It is expected the internet will be important tool to the process providing a means to submit and interrogate databases with increasing efficiency. The outcome will be wider use of LCA as a tool, a market for the publication of EPDs, and a reduction in cost of their development. Set within a context that is driving their publication, namely, BREEAM, EcoHomes, and the CSH, the timing is right to widen participation.

Design and LCA Tools

The above will be unsuccessful if EPDs fail to be integrated into the design and specification tools used by industry. Historically, BRE has developed its own, such as *The Green Guide to Specification* and ENVEST. The current strategy is to develop these tools further, building on their ability and capacity. In parallel, BRE is looking to form links to existing software's establishing interfaces with them and the Environmental Profiles database. In this way, EPD information can be embedded into tools already widely used by the UK design community assuring increased use of environmental performance information.

This work is to be paralleled with approaching LCA developers. Alliances with organizations like PE International, who developed GaBi [8] and PRe, who developed Simapro [9], are needed. Equally, links into databases such as Ivam, Ecoinvent, or the European platform on LCA must be forged.

In this way, placement of the LCA methodology and data can target two distinct user groups, those which are:

- design based (architects and specifiers)
- LCA based (research, consultancy, and supplier)

Sustainability Objectives and Responsible Sourcing

Inclusion of additional information in EPDs represents an important next development. To this end BRE is actively developing standards for health and well being and has established databases of costing information. The intention is to bring this data together within an EPD so that the wider sustainability characteristics of a product can be communicated.

BRE has also started the development of a responsible resourcing scheme that reflects the importance of the aspect in the construction sector. This will be a scheme for construction product manufacturers to demonstrate their commitment to environment and wider sustainability issues with rewards for environmental, social, and economic criteria. The core ethos is one of life cycle management and the bringing together of supply chain management and product stewardship. It allows differentiation between competitors with the assignment of company ratings but should have the capacity to bring together company performance, site performance and product performance. Links to existing schemes where possible are important. It will be evidence based as robustness is critical, but reflecting the newness of the agenda, allowance for actions and commitments will be made.

Civil Sector and Infrastructure

The building sector is well served by the Environmental Profiles methodology, LCA data, and tools such as *The Green Guide* and ENVEST. In the civil engineering sector there is no parallel information source and the industry is ill positioned to address the aspect of embodied environmental impact of the assets it constructs and builds. The industry requires a database from which decision support tools can be provided.

With the establishment of industry tools such as CEEQUAL [10], the framework now exists for embodied environmental impact to be addressed in civil's construction. This must be coupled with appropriate datasets and a decision support tool.

The civil sector presents a different group of issues to buildings (e.g., standards driven specification, significant impact from asset failure, huge use of steel, concrete and fills) and the model for buildings will not necessarily fit for infrastructure. In this respect, work is required to define the necessary objectives and the system required to deliver them. BRE is currently examining these issues and is looking at how they can be overcome.

Concluding Remarks

This represents a summary of ideas and actions currently being undertaken by BRE in the development of its EPD program the Environmental Profiles methodology. LCA is complex, but its application and use within the construction sector is entirely viable. This must be built on an agreed approach of which dissemination tools are crucial to success.

References

[1] Howards, N., Edwards, S., and Anderson, J., "BRE Methodology for Environmental Profiles of Construction Products, Components and Buildings," BRE, Watford, UK, 1999; www.bre.co.uk/envprofiles
[2] Anderson, J., Shiers, D., and Sinclair, M., *The Green Guide to Specification*, Blackwell Publishing, Oxford, 2002.
[3] ENVEST Software, BRE, Watford, UK.
[4] BREEAM and EcoHomes, which is the homes version of BREEAM, are products of BRE, Watford, UK.
[5] BRE Certification is a subsidiary company to BRE Ltd. and sits alongside the organization under the stewardship of BRE Trust.
[6] BSI ISO documents 14025:2006 and 21930:2007, ISO, Geneva, Switzerland.
[7] CEN/TC 350 "Sustainability of Construction Works," CEN, Brussels.
[8] GaBi, http://www.gabi-software.com/
[9] PRe, http://www.pre.nl/
[10] CEEQUAL is managed jointly by CIRIA and Crane Environmental. Contact CIRIA, London for product information.

Journal of ASTM International, Vol. 5, No. 2
Paper ID JAI101061
Available online at www.astm.org

M. Clapham,[1] *S. Foo,*[2] *and J. Quadir*[3]

Development of a Canadian National Standard on Design for Disassembly and Adaptability for Buildings

ABSTRACT: In recent years, both the public concern on environmental issues and the interest and demand for sustainable buildings have been growing worldwide. Architects, engineers, building developers, and buildings owners are feeling pressure to design, construct, and maintain buildings that respect sustainability and the environment. In support of sustainable development initiatives of governments and the building industry, the Canadian Standards Association (CSA) has established a Technical Committee on Sustainable Buildings, which has been tasked to develop national standards to advance the design, construction, and maintenance of buildings in a sustainable manner. This paper first discusses the standards development environment in Canada and the standards development process in CSA and goes on to describe the development of a new standard on the design for disassembly and adaptability of buildings.

KEYWORDS: adaptability, building design, building materials, building standards, construction debris, deconstruction, disassembly, environment, green building, reuse, recycling, sustainability, sustainable buildings

Introduction

Public concern on environmental issues has grown in recent years to the point where "sustainability" is becoming a commonly used, if poorly understood, term. Within this context, many products, manufacturing processes, and materials are under scrutiny by consumers, businesses, regulators, and others with respect to their value and environmental impact. Buildings are no exception. Architects, building developers, financiers, and owners alike are feeling pressure on several fronts from tenants, regulators, and evolving standards to factor environmental, social, and community considerations into the design and operation of buildings.

Design for disassembly and adaptability (DfD/A) are two approaches to sustainability that can reduce the environmental footprint of the building industry by reducing waste generation, improving building longevity, and reducing energy usage throughout by addressing this at the design phase. The disassembly component of DfD/A seeks to addresses this principle by making it easier to take products and assemblies apart in order to reuse or recycle materials. The adaptability component of DfD/A focuses on further reducing the footprint of the building industry by enabling the building to continue to be used beyond its original intent by readily accommodating substantial change within an existing physical asset.

The built environment represents one of the largest financial, physical, and cultural assets to the industrialized world. On the other hand, environmental burdens created by the growth of the built environment to keep pace with demand threaten to create a net negative environmental impact. DfD/A is one tool that is being advanced to address this threat to sustainability. The buildings being designed and constructed today are potentially enormous resources for the application of materials that can be reused and recycled in future construction projects. There are significant corresponding benefits in greenhouse gas reductions to be gained as well. It is estimated that between 3 and 5 million tons of construction, renovation, and demolition waste is disposed of annually in Canada, most of which can be recovered and diverted from landfill by applying design for disassembly and adaptability principles.

Design for Disassembly/Adaptability (DfD/A) is a relative new activity in the construction industry. Earlier practice in DfD/A and in design for deconstruction were highlighted in reports by Guy and Shell

Manuscript received February 15, 2007; accepted for publication January 17, 2008; published online February 2008.
[1] Senior Policy Advisor, Enhanced Recycling, Natural Resources Canada, Ottawa, Canada.
[2] Risk Management Specialist, Public Works and Government Services Canada, Gatineau, Canada.
[3] Consultant, Sustainability Edge Solutions, Toronto, Canada.

[1] and Catalli and Williams [2]. Webster and Costello [3,4] provided more recent and comprehensive references in the utilization of DfD/A strategies for improving the environmental and economic performance of buildings.

It is apparent that the DfD/A practice is gaining acceptance by the construction industry over the years, all within the context of various DfD/A principles. However, due to the lack of a standard procedure for quantifying the DfD/A design options, the environmental and economical benefits of DfD/A designs have not been fully realized by the construction industry. In a 2006 report and based on the DfD/A principles outlined in the CSA Guideline, PWGSC [5] proposed a framework that could be used to quantify and compare the environmental performance of DfD/A design options.

A new national "Guideline for DfD/A in Buildings, CSA-Z782-06" [6] under the auspices of the Canadian Standards Association (CSA) was published in Fall of 2006. Work is continuing to further develop the Guideline into a national Standard. In this paper, the standards development environment in Canada is presented. A short outline of the standards development process in CSA is given. Finally, a brief description of the new Guideline and its development is discussed.

Standards Development in Canada

The Standards Council of Canada (SCC) coordinates the National Standards System and ensures Canada's input on standards issues in international standards organizations. The SCC accredits Canadian standards development organizations and also approves Canadian standards as National Standards of Canada based on a specific set of requirements. The Canadian Standards Association is one of four accredited Standards Development Organizations in Canada.

Canadian Standards Association and its Standards Development Process

Established in 1919, the Canadian Standards Association is the oldest and largest accredited Standards Development Organization in Canada. CSA is a national, independent, not-for-profit membership association, serving business, all three levels of government and consumers in Canada and globally, with over 2600 published standards. CSA's 160 employees, with the involvement of its 9000 committee members develops product, system, and competency standards, codes, and other information products that promote public health and safety, improve the quality of life, preserve the environment, and facilitate trade. CSA's solutions address 54 different program areas such as environment, construction, quality, business management, energy, health care, public safety, and communications. CSA's overriding purpose is to make standards work for people and business.

CSA standards are developed using an accredited consensus-based process, ensuring respect for diverse stakeholder interests. Committees of volunteer experts develop the technical content of standards. These experts represent various interest groups, ensuring relevant and balanced stakeholder participation. The time and expertise of volunteer committee members results in valuable in-kind contributions to the development of standards that cannot be underestimated. The committee considers the views of all participants and develops the details of the standard by a consensus process. Substantial agreement among committee members, rather than a simple majority of votes, is necessary.

In accordance with the standards development process, CSA is obligated to formally review all standards for reaffirmation or development of a new edition at least as frequently as every five years. See Fig. 1 for a general overview of the CSA Standards Development Process.

Development of a National Standard on the Design for Disassembly and Adaptability

Exploratory Meetings

The development of the first guideline in Canada with specific focus on DfD/A started with three exploratory meetings among the main stakeholders between 2002 and 2003. The meetings were organized by two federal departments, Natural Resources Canada (NRCan) and Public Works and Government Services Canada (PWGSC), and the CSA. Participants of the exploratory meetings included government and industry representatives, CSA, and the academia.

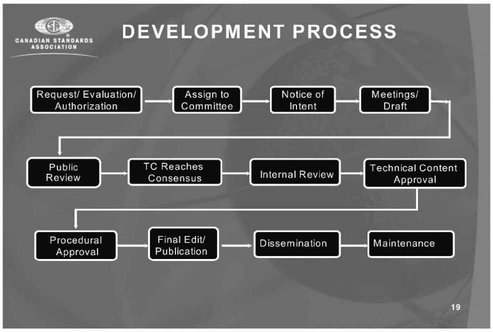


FIG. 1—*CSA standards development process.*

The main focus of these meetings was to discuss environment and sustainability issues in the built environment in general and the needs of the building industry in terms of the design, construction, and maintenance of buildings respecting sustainability requirements in particular. It was determined that while there were scattered technical documents related to sustainable buildings, there was a need for national guidelines and standards that would provide collective and national guidance to the industry to improve the sustainability of our built environment.

It was agreed that the development of national standards related to sustainable buildings should be done under the auspices of the CSA, a national standards development organization. Recognizing that the key stakeholders were well represented by the participants at these exploratory meetings, it was also acknowledged that this "exploratory group" could play a key role in the developing of national standards for sustainable buildings.

Technical Committee on Sustainable Buildings

In 2004, CSA established a new Technical Committee (TC) on Sustainable Buildings whose main responsibility was to develop technical standards for the design, construction, and maintenance of buildings respecting sustainability. Members of the new TC include most of the participants of the initial exploratory meetings and other new members in order to better represent the industry and to meet the CSA directives on the balanced matrix of member interests.

The Guideline for Design for Disassembly and Adaptability in Buildings was the first undertaking of the TC in terms of standards development. The aim of the Guideline was to provide guidance on the conceptual framework, concepts, and principles for the design of buildings following disassembly and adaptability principles. As this would be the first technical document specific for DfD/A, it was decided to have this first document published as a Guideline, which, together with feedback from the industry through field applications of the Guideline and new research findings, could be further developed in the future into a standard.

The Guideline was developed using a consensus-based approach using a PWGSC report [7] as the seed document. The first edition of the CSA Z782 Guideline for Design for Disassembly and Adaptability in Buildings was published in October 2006.

CSA Guideline for DfD/A in Buildings

The Guideline provides a framework for reducing building construction waste at the design phase, through DfD/A principles. The objective of this Guideline is to provide an overview of DfD/A principles and a method of defining the scope of integrating these principles into the design process to reduce the overall environmental burden associated with material assemblies. Its contents include DfD/A conceptual framework, DfD/A concept, specific principles, and annexes. The Guideline also reviews quantifiable metrics for each DfD/A principle that, subject to further development, can be assembled into a matrix or checklist to guide users in the direction of disassembly criteria design.

The Guideline can be used by architects, engineers, planners, building owners, and environmental

TABLE 1—*Sample assessment of design for disassembly options for flexible ducts [6].*

Design for disassembly summary/ flex duct	Versatility	Convertibility	Expandability	Durability	Accessibility	Independence	Simplicity	Reusability /recyclability	Refurbishability/ remanufacturability	Exposed reversible connections	Inherent finishes	Documentation of disassembly information
Flexible ducts can be reused and rerouted and are simple and easy to install	X		X				X			X		
Pre-insulated option is available							X					
Specify quick clamp connections										X		

professionals to increase their understanding of their options, and by other parties who are responsible for designing, constructing and demolishing buildings. The Guideline is not to be used as a design tool; rather, it can be used to aid the comparison of environmental performance of various design options within the context of DfD/A principles. The Guideline outlines and discusses the following 14 DfD/A principles:

- versatility
- convertibility
- expandability
- accessibility
- documentation of disassembly information
- durability
- exposed and reversible connections
- independence
- inherent finishes
- recyclability
- refurbishability
- remanufacturability
- reusability
- simplicity.

For each principle, a general discussion is given along with examples of potential strategies and measurable metrics. Using “versatility” as an example, the general discussion would start with “versatile buildings and spaces lend themselves to alternative uses with minor system changes.” Examples of potential strategies include building areas for multiple purposes part of the design and construction, e.g., a gymnasium can double as a community theater. Measurable metrics can include the percentage of floor space or building footprint that has multiple uses on a daily, weekly, or monthly basis, without requiring changes to the main features of the space.

Using “durability” as a second example, the general discussion defines durability as “the ability to exist for a long time without negatively impacting building performance or service life” and that “durability provides reduced environmental impact by minimizing the maintenance or replacement of a product.” Examples of potential strategies include the use of materials with a high durability rating that require less frequent maintenance, repair, or replacement. Measurable metrics can include the cost of maintenance as a percentage of purchase price and the lifespan of a given product compared to alternative products that serve the same function at the same performance.

The Guideline also includes an Annex on the feasibility assessment of design for disassembly options. A table was given to illustrate examples of specific elements or components/assembles being assessed for each DfD/A principle. Examples are related to mechanical systems, such as ducting, diffusers, pipes, flexible tubing, and connectors. Examples on flex duct options are shown in Table 1.

The same process can be used for other elements at the structural, building envelope, services, or fit-up level. The tabular format can be used to assess early outline specifications to ensure DfD/A are being addressed, and to identify opportunities for improvement.

CSA Standard for DfD/A in Buildings

Work has begun towards the further development of the Guideline into a national standard. Communication strategy is being developed for promoting the use and the acceptance of the Guideline by the industry. There is an effort to collect data on the use of DfD/A principles and the corresponding environmental benefits from past, current, and future field applications. New research such as the further development of the DfD/A principles into framework, indicators, a method for understanding potential performance and a procedure for evaluating/comparing relative environment performance of DfD/A design options for office fit-ups [5], is being considered or carried out. The plan is to start the new Standard development about 18 months after the release of the Guideline, i.e., in the spring of 2008.

Summary

In general, the main objectives of building codes and standards for the design and construction of buildings are health and safety. Environmental and sustainability performance of buildings are usually not part of the code requirements. In an effort to support and promote sustainable development, there is a need for the development of guidelines and standards, which provide guidance on the design, construction, and maintenance of sustainable buildings. Design for disassembly and adaptability is one tool that can improve the sustainability of a building. The Canadian Standards Association provides a forum for common ground, consensus building, and continual improvement of standards development in Canada on sustainable buildings. Upon the publication of the first edition of a new CSA Guideline for Design for Disassembly and Adaptability in Buildings in 2006, the CSA, together with the industry, is working towards information dissemination and further development of the Guideline into a national Standard.

Acknowledgments

This paper has been prepared on behalf of the CSA Technical Committee on Sustainable Buildings. The contribution of all the members of the Technical Committee towards the development of Z782-06 is gratefully acknowledged. Special recognition is due to Natural Resources Canada and Public Works and Government Services Canada for their financial support for the development of Z782-06. Permission by CSA to include Z782-06 in this paper is appreciated.

References

[1] Guy, B. and Shell, S., "Design for Deconstruction and Materials Reuse," Proceedings of the CIB Task Group 39 – Deconstruction Meeting, CIB Publication 272, 2002.

[2] Catalli, V. and Williams, M., "Designing for Disassembly," *Canadian Architect*, Vol. 46, No. 1, pp. 27–29, 2001, http://home.primus.ca/~chapman/articles_200101.html.

[3] Webster, M. D. and Costello, D. T., "Designing Structural Systems for Deconstruction: How to Extend a New Building's Useful Life and Prevent if from Going to Waste When the End Finally Comes," *GreenBuild Conference*, Atlanta, GA, November 2005.

[4] Webster, M. D., "Structural Design for Adaptability and Deconstruction: A Strategy for Closing the Materials Loop and Increasing Building Value," *Structural Engineering Institute (SEI) Congress*, Long Beach, California, May 2007.

[5] Public Works and Government Services Canada (PWGSC), "Design for Disassembly and Adaptability for Fit-Up in Office Retrofits: Framework, Indicators and Method for Understanding Potential Performance," PWGSC, Gatineau, Quebec, Canada, 2006.

[6] Canadian Standards Association (CSA), "Guideline for Design for Disassembly and Adapatability in Buildings, CSA-Z782-06," CSA, Toronto, Canada, 2006.

[7] Public Works and Government Services Canada (PWGSC), "Designing for Disassembly on Fit-Up and Refit Projects," PWGSC, Gatineau, Quebec, Canada, 2004.

Journal of ASTM International, Vol. 5, No. 2
Paper ID JAI101069
Available online at www.astm.org

Liu Gang[1]

The Review on Sustainability of National Building Standard Design in China

ABSTRACT: There are more than 40 billion square metres of buildings in China and the number is forecasted to grow by 1.6~1.9 billion square metres year over year by 2020. China has been facing serious energy and environmental challenges to address sustainable development. The National Building Standard Design (NBSD) is a set of standard drawings, compiled according to Chinese building standards and codes by the Ministry of Construction (MOC), including construction details, building components, selection and installation of equipment, etc. The NBSD has been tested by real projects and market feedback. It's crucial to implement it to increase the efficiency of the construction process. The paper describes the historical development of NBSD and the contribution to sustainable development in China's construction sector. The paper also introduces the effects and new trends of standard designs on sustainability in China.

KEYWORDS: sustainability, National Building Standard Design (NBSD), China

Introduction

National Building Standard Design (NBSD) is a set of standard drawings, compiled according to Chinese building standards and codes by the Ministry of Construction (MOC), including construction details, building components, selection and installation of equipments, etc. [1]. The initial purpose of developing the NBSD was to meet the demands of the first upsurge of construction in the 1950s in China. At that time, compared with huge construction projects, there were few design professionals, skilled workers, or state-of-the-art technologies in the construction sector. The China Institute of Building Standard Design & Research (CIBSDR) was founded in 1956, and authorized by the central government to develop NBSD. As the only NBSD development organization, CIBSDR works together with MOC to organize National Technical Committees, having experts from throughout the country, to supervise the development process for the NBSD.

Since economic reform began in the 1980s, soaring economic development has been recorded in China. For the construction industry, in 2002, there totaled 40 billion square metres of buildings. It is expected that another 30 billion square metres will be added by 2020 [2]. The greatest challenge in the face of this anticipated expansion is that the construction process is less industrialized; moreover, typical Chinese design and construction crews are not very professional. Most construction crews are comprised of migrant workers, who have little training in construction skills and very little idea of how to properly put together even basic assemblies. NBSD helps architects and engineers to improve design quality, and guides construction personnel to build it properly. NBSD has fulfilled such critical needs for the past 50 years. For example, there are more than 6 billion square metres of single-floor factory buildings that applied NBSD in the construction process. Currently, 90 % of construction projects comply with the NBSD in their design documents.

The NBSD now covers nine disciplines:

1. architecture
2. structure
3. water supply and drainage
4. heating, ventilation and air conditioning (HVAC)
5. power
6. electric

Manuscript received February 20, 2007; accepted for publication December 17, 2007; published online February 2008.
[1] China Institute of Building Standard Design & Research, Beijing, China

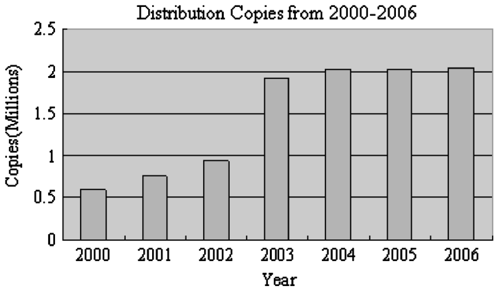


FIG. 1—*Annual circulation from 2000–2006.*

7. electronic
8. civil defense
9. municipal road

Since the 1950s, CIBSDR has compiled a collection of nearly 1900 drawings, of which 300 still apply today. In total, more than 38 million copies of drawings have been distributed. Annual circulation is more than 2 million (Fig. 1).

From the 1980s, CIBSDR has revamped its strategy to focus on sustainability in the construction sector. The purpose of NBSD is to promote new materials, products, advance technologies and methods into construction practice, to improve energy, water, lands, and materials efficiency, and finally to contribute sustainable development in the construction industry.

NBSD as Facilitator of Implementing New Energy Building Standards in China

Background

As a result of rapid economic development, China is facing serious energy and environmental issues. In the process of construction and operation of buildings, direct consumption of energy increases greatly, and now comprises nearly 30 % of total energy consumption in China [2,3] (Fig. 2). According to the World Bank, per capita water resources in China are about 2170 m^3 [4], only 31.6 % of the world average. The major cities in China have encountered heavy air pollution. To meet the great challenges in sustainable development, the Chinese Government has set the goal that energy consumption per GDP be decreased 20 % from 2005 to 2010.

However, it's still a difficult challenge to cut down energy consumption and improve resource efficiency in China. In the first six months of 2006, energy consumption per unit of GDP actually increased

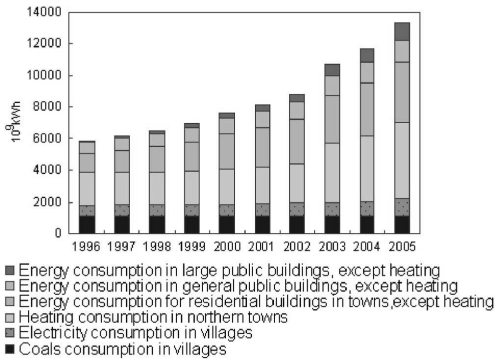


FIG. 2—*Buildings energy consumption in China from 1996–2005.*

0.8 % instead of decrease as planned. By the end of year, the energy consumption in 2006 per unit of GDP fell 1.2 %, but did not reach the original goal of 4 % [5]. In public speeches, the Minister of China's Ministry of Construction (MOC) also mentioned several times, that 95 % of existing buildings and more than 80 % of new ones failed to meet the requirements of the standards from an energy efficiency viewpoint.

New Energy Building Standards in China

In China, standard system for buildings includes national standards (standard number begins with "GB") and industry standards (standard number begins with "JGJ"). The last two or four digits represents the year. There are two types of both national and industry standards: mandatory and recommended. Recommended standard numbers begin with GB/T or JGJ/T, where T stands for recommended. For example, *Evaluation Standard for Green Building* (*GB/T50387-2006*), is the recommended standard and published in 2006. Because of different climate and economic situations, some provincial governments also established local standards, which include more details to carry out national and industry standards.

Since the 1990s, and especially in the past three years, MOC has been developing and implementing many building energy standards and codes:

- *Thermal Design Code for Civil Building (GB50176-93)*
- *Energy Conservation Design Standard for New Heating Residential Buildings (JGJ26-95)*
- *Design Standard for Energy Efficiency of Residential Buildings in Hot Summer and Cold Winter Zone (JGJ134-2001)*
- *Design Standard for Energy Efficiency of Residential Buildings in Hot Summer and Warm Winter Zone (JGJ75-2003)*
- *Design Standard for Energy Efficiency of Public Buildings (GB50189-2005)*
- *Technical Code for Solar Water Heating System of Civil Buildings (GB50364-2005)*
- *Evaluation Standard for Green Building (GB/T50387-2006)*
- *Code for Acceptance of Energy Efficient Building Construction (GB50411-2007)*
- *Design standard for energy efficiency of residential buildings (draft)*
- *Code for acceptance of energy efficient building construction (draft), etc.*

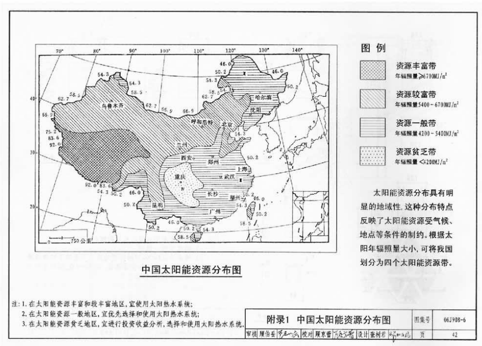
Many local governments also compiled local standards and regulations to meet those requirements. However, the regulation of energy and its enforcement is still a new concept in China's building sector. The most challenging thing is how to apply the codes and standards. Because of a lack of experienced professionals, it's difficult to deploy those standards in underdeveloped region of China. In such cases, the National Building Standard Design (NBSD) has played a vital role to help completely implement the standards' requirements, and has made a huge contribution in clarifying exactly what people need to do to comply with these new efficiency standards.

Achievements of NBSD Regarding Energy Efficiency and Renewable Energy

General—To improve building performance and promote new technologies and products, CIBSDR first introduced Exterior Insulation and Finish System (EIFS) in NBSD in 1999, and published new design standards regarding energy efficient windows, new types of roof systems, and radiant floor heating systems in 2003.

After developing the National Standard, *Technical Code for Solar Water Heating Systems for Residential Buildings* in 2005, CIBSDR published NBSD-*Solar Water Heater Selection and Installation* (Fig. 3) to spur the application of solar energy.

NBSD Series on Energy Efficiency in 2007—To help designers and construction crews fully comply with new energy efficiency standards, CIBSDR has published 22 volumes of NSBD series on Energy Efficiency in 2007, covering architecture, water supply and drainage, HVAC, and electrical. In the architecture volume, it includes energy efficient construction details for walls, roofs and windows; energy efficient construction for public buildings in different climate regions; outside shadings; and renovation for existing buildings. In the HVAC volume, it includes selection and installation for the turbine roof ventilation system, heat recovery system, and solar collection system; design of installation for heat-pump



(*a*)

(*b*)

FIG. 3—*Page from Solar Water Heater Selection and Installation and Application in LiJiang town.*

system, and ice storage system, etc.

At the same time, in cooperation with the MOC and more than 15 famous Chinese design and research institutes, CIBSDR has published the *National Technical Measure for Design of Civil Construction*, *Special Edition-Energy Conservation*, (Fig. 4) in which, many advanced energy efficient technologies are discussed.

FIG. 4—*National Technical Measure for Design of Civil Construction, Special Edition-Energy Conservation.*

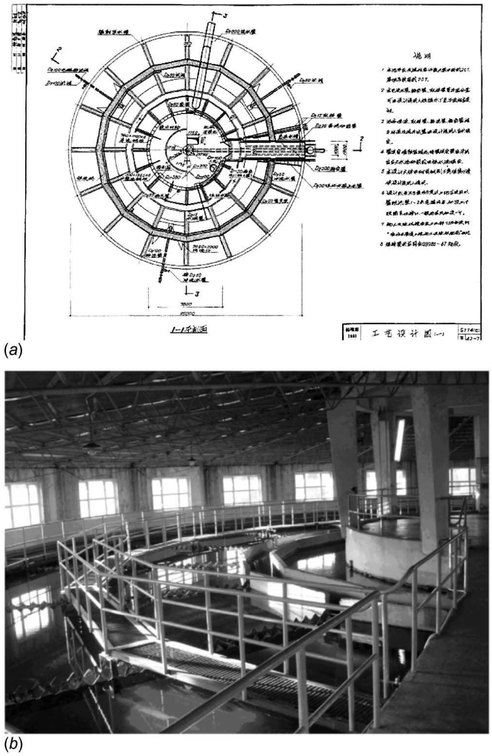


FIG. 5—*Page of Accelerated Clarifier in NBSD and Application.*

Promote Advanced and Standardized Construction Methods in China

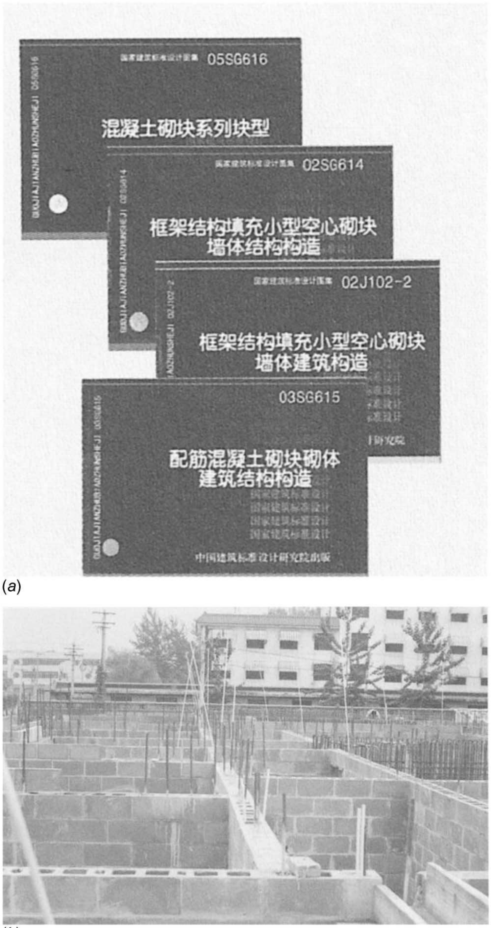
Beside the achievement in energy efficiency, NBSD also helps the construction sector promote advanced and standardized methods.

Water Supply Engineering

In 1985, in response to the United Nations agreement on International Drinking Water Supply and Sanitation Decade, the Chinese Government commissioned CIBSDR to compile a series of NBSD about Drinking Water Supply in Rural Areas, aimed at helping people to have safe and healthy drinking water in rural areas. This series of NBSD included 55 volumes, and has contributed greatly in establishing new water supply systems in rural areas (Fig. 5).

Building Materials

NBSD also helped promote building materials changes in 1990s by replacing clay brick with concrete air brick or cork brick. Clay brick is the traditional material, but it requires more soil to fabricate. With the boom of construction, using clay bricks had damaged vast tracts of farmland. Hollow brick and perforated brick can be made by using recycled materials (Fig. 6). As a result, they are considered environmentally friendly products. By requiring architects and engineers to apply new materials, NBSD assisted the nation to preserve precious land and soil resources.



(*a*)

(*b*)

FIG. 6—*NBSD about concrete air-brick structure and application.*

Series NBSD of Residential Building in Rural Areas

Background of the Project—In China, more than 60 % of the total population lives in rural areas [4]. It's a great challenge to improve housing facilities of people in rural areas, and at the same time, preserve the ecological balance and local culture. As the project leader, CIBSDR organized 23 top research institutes, universities, and design agencies in China, to carry out a research project entitled *Rural Areas Residential Zones Planning Guide and Standardization in Construction Process*. The project was one of the National Key technologies R&D Programs of 2000–2005.

Obstacles to Develop Sustainable Buildings in Rural Areas in China and Suggested Solutions—The research team investigated 83 towns, 154 residential zones in 21 provinces around the country, in order to learn more about the real situation in rural areas across different parts of China. Through the study, the team found that because of differences in natural conditions, climate, and local cultures, house construction has varying architectural characteristics. However, in recent years, there was a trend of copying planning and architecture design from cities in some developed rural areas in south China, which makes houses look similar in most towns. In some cases, because of insufficient involvement by professionals,

TABLE 1—*Suggested key recommendations in Standards for the Residential Building Design in Rural Areas.*

		Small	Large	Other Recommendations
Use of area/m^2		60–90	90–150	
Functional use of space	Living room	14–18	18–30	Width ≧3.6 m
	Main bedroom	8–12	12–16	Width ≧3 m
	Single-bed room	6–8	8–10	Width ≧2.4 m
	Kitchen	6–8	8–12	operating table ≧2.7 m
	Washroom	3.5–4.5	4.5–6	
	Entrance space		≧1.5 m^2	
	Balcony		≧2 m^2	

the construction process used more lands and even damaged the local environment, but the houses still could not meet the requirements of local people. It's critical that those negative trends be stopped and improvement be made in the quality of the design and construction process of houses in order to ensure more sustainable development for local people.

In the *Rural Areas Residential Zones Planning Design Guide* [6], (see Table 1), the research team provided several principles:

- Respect local traditional architectural culture.
- Promote land efficiency in the design process.
- Apply energy-saving technologies and use alternative/renewable energy.
- Utilize local and renewable materials as much as possible.
- Reduce water consumption and protect water quality.

The report also suggested some key requirements for standards. The main purpose is to limit the functional areas of the house, thereby saving construction land.

Combine Local Architectural Culture with Modern Technologies in NBSD—To promote traditional architectural design and avoid homogeneous designs, the research team selected eight typical provinces (Figs. 7–9) with local architectural characteristics, and studied traditional village planning, architecture design, structural engineering, interior design, and specially analyzed how to combine those characteristics with new materials and modern building technologies. CIBSDR published an eight-volume NBSD: *Houses in Rural Areas with Traditional Characteristics* [7] in eight typical geographical areas. According to the research reports, CIBSDR also provided a nine-volume NBSD [8] to demonstrate housing designs in northeastern, northern, northwestern, southwestern, eastern, and southern areas of China. Each volume

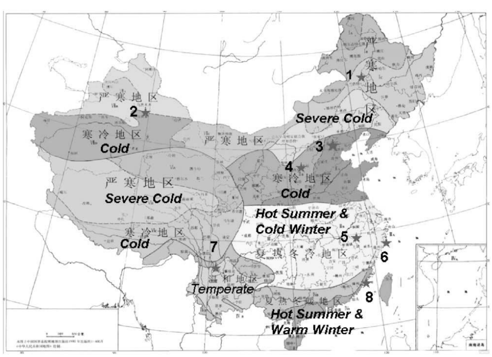


FIG. 7—*Selected eight typical areas in China Climate Zone Map.*

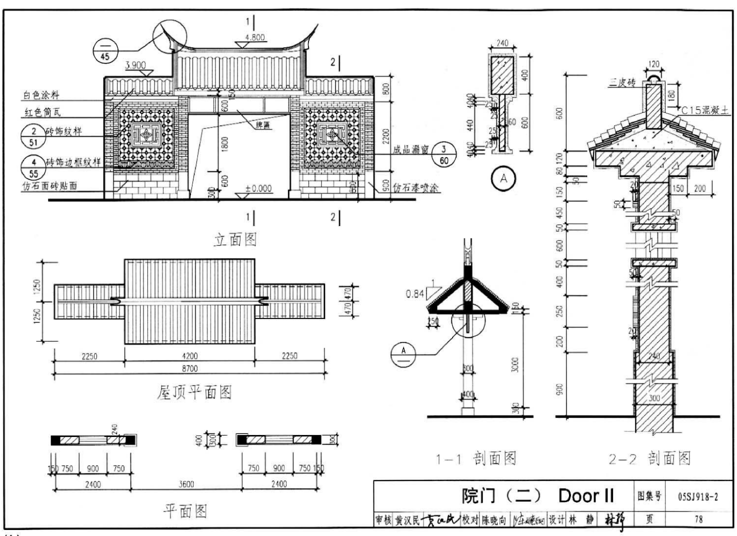
1. Northeastern China
2. Tulufan, Xinjiang Province
3. Beijing
4. Middle of Shanxi Province
5. Huizhou, Anhui Province
6. Taizhou, Zhejiang Province
7. Lijiang, Yunan Province
8. Quanzhou, Fujiang Province

includes eight to ten types of houses, with architecture, structural engineering, water supply and drainage, HVAC, and electric detailed designs. It recommends using a solar water supply system or solar heating system in suitable areas. Those NBSD can be used directly in the construction process.

It's the first time in China to combine traditional elite architectural design and modern building technology in rural areas. It provides local people a choice to live in houses suitable for local life, with traditional architectural characters, but more resource efficient than older homes.

In March 2006, MOC decided to distribute this series of NBSD to 1887 key towns through the country, and prepares to set up demonstration towns in the near future.

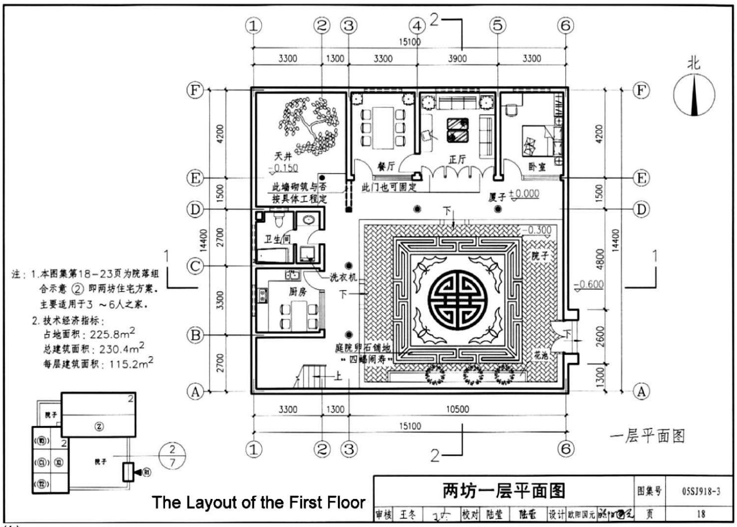
(*a*)



(*b*)

FIG. 8—*Traditional door in Quanzhou, Fujiang Province and drawing in NBSD.*

(*a*)



(*b*)

FIG. 9—*Traditional house in Lijiang, Yunnan Province and layout in NBSD.*

Conclusions

In recent years, the concept of green buildings has never been more popular in China. Nevertheless it remains a long way to turn the ideas to reality, and be appropriate to China's social, economic, and environmental context. All involved actors should deeply understand how to really apply integrated design approach from a whole life cycle perspective, instead of carrying on the traditional isolated approach in design for each specific feature or life cycle stage.

"Think Globally, Act Locally." From the 1980s, NBSD has developed suitable methods in China for sustainable development in the construction sector. Through the introduction of new materials and technologies, NBSD has contributed to improving the quality of architectural design and construction projects. At the same time, NBSD also has increased land, energy, water, and materials efficiencies in the past 20 years. NBSD will continue to promote the integrated design approach and provide more practical methods in sustainable development for the entire construction community in China.

References

[1] Regulations on Administration of Construction Standard Design, Ministry of Construction P.R. China, 1999, http://old.cin.gov.cn/quality/file/2001072406.htm

[2] Qiu, B., "China's Energy Strategy and Green Building Prospect," *Articles Collection of 1st International Conference on Intelligent and Green Building Technologies*, Beijing: China Architecture & Building Press, 2004.

[3] Tsinghua University Building Energy Research Centre, 2007 Annual Report on China Building Energy Efficiency, China Architecture & Building Press, 2007.

[4] The World Bank, Little Green Data Book 2006, Washington DC, 2006, http://siteresources.worldbank.org/INTEEI/936214-1146251511077/20916989/LGDB2006.pdf

[5] Wen, J. B., Report on the Work of the Government, Delivered at the Fifth Session of the Tenth National People's Congress on March 5, 2007, http://news.xinhuanet.com/english/2007-03/16/content_5857166.htm

[6] Final Reports of Project: Rural Areas Residential Zones Planning Guide and Standardization in Construction Process.

[7] China Institute of Building Standard Design & Research, Houses in Rural Areas with Traditional Characteristics *(05SJ918-1~8)*, Beijing, China, 2005.

[8] China Institute of Building Standard Design & Research, Residential Houses Demonstration Design Houses in Rural Areas *(05SJ917-1~9)*, Beijing, China, 2005.

Journal of ASTM International, Vol. 5, No. 1
Paper ID JAI101095
Available online at www.astm.org

Joel Ann Todd[1] *and John Boecker*[2]

Continuous Improvement of the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED®) Rating System™

ABSTRACT: The U.S. Green Building Council's (USGBC) Leadership in Energy and Environmental Design (LEED) Rating System™ has had a significant impact on the market in the United States and is beginning to affect markets around the world. First launched in the late 1990s, LEED has undergone periodic revision, including updates as well as addition of new versions that address different markets and enhance technical quality of the credits. In 2006, the USGBC initiated a continuous improvement process that will result in a LEED system that is more technically robust and easier to use. This paper describes improvements that are underway using a proposed framework for analyzing green building rating systems. This framework encourages a broader and deeper analysis of rating systems, looking beyond the technical metrics to include the purpose and goals of the system, the context in which it is applied, the scope of the system, the metrics, and the processes used in its implementation.

KEYWORDS: sustainable design, rating system, green buildings

Introduction

The U.S. Green Building Council's LEED Rating System™ has had a significant impact on the market in the United States and is beginning to affect markets around the world. First launched in 1999, LEED has undergone periodic revision with addition of new versions that address different markets and enhance technical quality of the credits. In 2006, the USGBC initiated a continuous improvement process that will result in a LEED system that is more technically robust, more responsive, and easier to use[3].

This paper uses a recently developed framework for thinking about rating systems to present highlights of the LEED improvement process, thus illustrating the use of the framework and providing information on the process of revising LEED. The effectiveness of the framework in organizing the analysis and contributing to findings will be assessed. The authors of this paper were principal authors of the framework.

Overview of the Framework

The framework used in this paper is taken from a report prepared for the U.S. General Services Administration entitled "Seeing Beyond the Metrics: Lessons about Rating Systems from GBTool and Other International Systems" [1]. The premise of the report is that we need to look beyond the criteria and credits as we examine and think about green/sustainable building assessment and rating systems. Focusing only on criteria and credits is just the tip of the proverbial iceberg—a deeper, more intentional examination of these systems will produce rating systems that are more effective in achieving their goals. Further, by looking beyond the metrics, we can explore how rating systems can play different roles—in stimulating further dialog on the meaning of sustainable or regenerative design, the role of the built environment in communities, and other important questions. As stated in the report:

"When we think about rating or assessment systems, we generally focus on *what* criteria or compo-

Manuscript received March 2, 2007; accepted for publication November 27, 2007; published online December 2007.
[1] Environmental Consultant14 Webb Road, Cabin John, MD 20818.
[2] 7Group2455 Rosstown Road, Wellsville, PA 17365.
[3]The concept of "continuous improvement" of LEED evolved from the system of issuing version updates, similar to that used for computer software (LEED 1.0, 1.1, 2.0, 2.1, etc.). This effort had been called "LEED Version 3" prior to the shift to continuous improvement. The change was an effort to avoid sudden lurches from one version to another, with the concomitant user confusion and uncertainty.

nents are included and *how* those criteria are measured. A literature has grown up around comparisons of various rating systems based upon these parameters. We have learned, though, that it is important to understand the *context* in which such systems are implemented as well as the *processes* used to develop and implement them. In other words, when we think about rating systems, we need to expand our approach in several directions, and we need to think about how the various elements of a rating system relate to one another, producing an integrated whole.

“Rating systems don’t exist in a vacuum. They are created for a specific purpose (or for more than one purpose), and for a particular place, whose characteristics establish the social, cultural, economic, and physical context. Accordingly, *purpose* and *context* provide the foundation for a rating system, and they encompass it; they are the sphere in which it exists. The rating system itself is defined primarily by the *scope* of its contents, and by the *technical metrics* used to measure performance within that scope. Tying these factors together is *process*—this includes the process used to develop and maintain the rating system, the process by which buildings are rated, and the process by which buildings are designed,” operated, and renovated.

“Thus the five key factors that inform and constitute a rating system are:

- **Purpose**—*why* we want the rating system
- **Context**—*where* (in the broadest sense) we measure and what that means
- **Scope**—*what* is measured
- **Technical metrics and scoring**—*how* we measure
- **Process**—how we *make it all happen*.

“Our aim here is to think more intentionally about all five of these critical factors and how they fit together, so that we can arrive at a much deeper understanding of measurement and its role in helping us comprehend more fully the benefits and shortcomings of green buildings” [2].

This framework evolved from an examination of “lessons learned” from rating systems around the world. The authors recognized that a simple comparison of metrics and methods would not ask or answer the more important questions. Thus, the report refocused on an “exploration of the role that rating systems play in the future of the green building movement, particularly in terms of setting the boundaries and agenda for how we perceive measurement, what we choose to measure, why we measure, and how we use the results” [3]. The framework could be useful in several types of analyses:

- Comparison of two or more rating systems. There have been numerous comparative analyses of various green building rating systems from around the world—many sustainable design conferences include technical presentations on this topic; journals regularly include technical papers comparing systems; and organizations considering adoption of a rating system usually conduct formal or informal comparisons to ascertain which system might meet their requirements. Most of these analyses focus on the technical aspects of the systems—the metrics (criteria or credits), the system for scoring, and the methods for weighting the importance of various categories. In some cases, they include approaches for presenting results and methods of verifying achievements. The framework could encourage these comparative analyses to expand their scope and explore deeper questions. It could also foster comparability among the studies themselves, leading perhaps to greater understanding.
- Examining a single rating system to identify potential improvements. Most revisions of rating systems focus on improving the metrics and making the process more efficient for users. Sponsors of rating systems also respond to requests to expand the scope of rating systems to additional building types or to additional categories of criteria. Under pressure to keep rating systems up-to-date, accurate, and easy to use, sponsors rarely have the time to step back and think deeply about their systems. The framework could assist in organizing such an effort, focusing attention on the individual components of the system as well as the interactions among them.
- Furthering our thinking about how rating systems can be most effective and what roles they can play in efforts to move toward a sustainable or regenerative world. As we seek to improve our ability to measure various aspects of building performance, it is easy to forget the larger questions of how rating systems can be more effective in achieving goals and what roles they can play in sparking and facilitating dialog on important issues. In exploring the interactions among the five factors of the framework, we are encouraged to look more deeply at how our goals affect the scope

of the systems and what it means to expand the goals and scope; how the system fosters dialog and involvement of communities (or does not); and how the system builds a platform for integration of project teams and integration of teams with communities (or does not) [4]. It encourages us to think about what is important and how the rating system can focus attention and action on important concerns, not just those that are easiest to measure.

Application of the Framework to LEED Continuous Improvement

During 2006, the U.S. Green Building Council initiated a process to gather ideas for improving LEED from a diverse group of LEED users and experts in sustainability and sustainable design. The suggestions ranged from changes in specific LEED credits to larger actions that had implications beyond LEED. Some of the suggestions can be implemented almost immediately while others would require multi-year efforts. The suggestions were summarized and then reviewed and prioritized by the LEED Steering Committee of the USGBC. Work was initiated to address the priority ideas.

The Framework described above can be used to stimulate ideas for improving an assessment system and to organize these ideas. The authors applied the Framework to the LEED improvement ideas to illustrate its usefulness as an organizing tool and to ascertain what insights could be gained that could benefit the LEED improvement process. Each of the sections that follow begins with a brief quote from the report to define the topic.

Purpose

Definition of "Purpose"

> "'Purpose' articulates the goals and objectives we want to achieve through the use of an assessment system. The assessment system's scope, levels of rigor, and process are affected by the goals of the rating system. Depending on the intended role of a rating system, its characteristics can be quite varied…It is not often easy to adapt a system designed for one goal or purpose to fulfill other goals…" [5].

To be effective, rating systems should be designed to their intended purpose or use. For example, a system designed to be used for research purposes will be different from one designed for market transformation. In the first system, rigor and precision will be most important; in the second, simplicity, practicality, and positive rewards will gain in importance. A system designed as a third party assessment tool might not be an effective design tool for project teams.

Rating systems should also be designed to achieve their environmental (and other) purposes or goals. In many cases, these goals are implicit rather than explicit. They are evident in the scope of the system, the items included and omitted. Many systems use the same set of criteria or categories of criteria, without going through a careful process of goal-setting. Developing countries have challenged this approach and have established social and economic goals as well as environmental goals.

It is important to remember that rating systems are only one tool for reaching goals. It is important to consider other potential tools to determine where the rating system might be particularly effective and where other tools might be more appropriate.

"Purpose" in LEED Improvement

Examining the purpose of LEED and its specific goals was an important component of the 2006 LEED improvement process. The goal of LEED has always been "market transformation" so this exercise examined questions such as: What are the most important issues that market transformation should address? How can LEED most effectively transform the market to achieve its goals?

To explore these questions, the USGBC included discussion of goals at workshops around the country and convened a "visioning summit" of thought leaders to examine how the USGBC and LEED could have the most impact.

An important outcome of this process is an explicit emphasis on climate change. This newly articulated goal, or purpose, will translate into LEED improvement in several ways. First, technical metrics will be revised to reflect the increased emphasis on climate change. An immediate change to the Energy and Atmosphere section of LEED has been proposed, raising the minimum energy performance of commercial projects (requiring that projects earn at least two energy efficiency points under E&A Credit1). Further, all new commercial projects will be required to reduce CO_2 emissions by 50 %, an effort that will integrate energy, water, transportation, and materials actions.

The USGBC recognized that the visioning process is too important to be relegated to an ad hoc exercise. An ongoing engagement of thought leaders and practitioners in exploring the purpose and goals of the USGBC in general and LEED in particular is being established. This effort will provide guidance to the USGBC in general and the LEED activities in particular on how they can exercise leadership on importance environmental and societal challenges, through the LEED rating system and other actions.

Context

Definition of "Context"

> "'Context' comprises all of the environmental, social, cultural, economic, historical, geographic, climatic, governmental, traditional, and other outside factors that affect how we think about sustainable design, how we approach it, how we do it, and how we measure it in a given place. Context examines "where" in a very broad sense, and although it encompasses issues ranging from local to global considerations, context focuses on "place"…The better our understanding of the context in which we work, the more appropriate our actions will be, the more benefit we can provide, and the more accurately we can measure the effects of our actions…Context both *enables* by providing opportunities, and *impedes* by providing barriers. Our awareness and subsequent exploration of context defines and enlightens" [6].

Climate is the most frequently cited aspect of context for buildings. However, there are many other context factors that provide opportunities or barriers to green building, and define what is most appropriate in a given place. These factors can include other elements of the natural environment such as watershed characteristics; historical habitat and human development patterns; and local, regional, and global environmental issues. Context can also include cultural and historical norms, values, expectations, and traditions; priorities of government and society; stage of industrial and technological development; urban, rural, or suburban setting; capabilities and available resources; and applicable codes, policies, regulations, treaties, and other requirements. Context also includes the status of the local "green building" movement—in some areas, building green is becoming the norm, while in other areas it is still regarded as a novelty.

The scale of the context varies from the immediate site or neighborhood scale to regional, national, and international scales. The scale can be determined by the natural environment or by human constructs, such as governmental boundaries. It is critical to select the appropriate scale when exploring these context factors. And, of course, many of these factors are interdependent.

"Context" in LEED Improvement

LEED was developed by and for the U.S. market. This attention to context defined the overall approach. LEED was designed as a voluntary system, driven by project teams rather than regulatory agencies, with credits to reward positive actions. This approach is quite different from a comprehensive assessment system that scores on all criteria and gives negative as well as positive scores, as is used in many other countries. This responsiveness to the U.S. market has been a major factor in the success of LEED in this country. In this sense, then, LEED is very context sensitive.

In another sense, however, LEED does not reflect context—as a national system, only a few of LEED's prerequisites and credits reflect the differences that exist around the United States, in terms of climate, infrastructure, culture, etc. The LEED improvement process recognizes the potential importance of these distinctions and is establishing a process for identifying where regional adaptation is appropriate and proposing context-specific changes. Initial questions to be explored include: How is "region" defined—by climate, ecological features (airshed, watershed), governmental boundaries, urban areas, etc.? Different definitions could be relevant to specific LEED metrics. A key question in this process will be how LEED can be protected as a national rating system while encouraging regionalization that makes it more effective? This will be crucial to avoid confusing users and presenting manufacturers and distributors of products with bewildering complexity.

Scope

Definition of "Scope"

> "'Scope' is *what* a rating system addresses (and doesn't) and *why*. Rating system scope is often defined by what is considered important, as defined by its purpose, and by what is measurable and quantifiable…As we expand the scope of our rating systems, we need to keep in mind our overall goals to avoid scattershot efforts that could overburden our systems rather than improve them" [7].

Most rating system sponsors around the world have expanded the scope of their systems over time. Most begin with a system targeted to one building type and expand to cover other building types. Most also begin with a system that covers design and construction and expand to cover operations. In a few cases, sponsors have expanded the scale addressed by the system, moving beyond the building and its immediate site to include the neighborhood or developing community/ urban scale systems. A few have also expanded to include the processes used by project teams in design and construction. Finally, in developing countries in particular, scope is being expanded to include social and economic issues as well as environmental issues.

Expansion of scope can occur in response to demand from the market or as a consequence of newly articulated priorities. Sometimes, scope can be expanded as new metrics become available.

"Scope" in LEED Improvement

The scope of LEED has been expanding since its first launch. Almost immediately, work began on versions of LEED for buildings in different stages of their life cycle—to address not only new construction, but also operations and maintenance of existing buildings. The scope was then expanded to include fit-out of commercial interiors and new core and shell buildings. In addition to these new versions of the rating system, work began on application guides, which were intended to tailor an existing LEED rating system to a particular building type; application guides for healthcare facilities, schools, laboratories, retail establishments, and other buildings were developed.

All of these expansions of scope were limited to buildings and their component parts and sites. Now, LEED's scope is expanding to the neighborhoods surrounding buildings. LEED for Neighborhood Development marries the LEED approach with concepts of smart growth and new urbanism to address critical issues of neighborhood design, transportation, creating linkages and community, and others. Expansion of scope in this direction is consistent with similar efforts in other countries as we recognize that a "green" building in the wrong location and surroundings is certainly not "sustainable" and that our emphasis on Integrated Design should apply to integration of buildings with their communities as well as integration of project teams. In fact, this approach expands the scope of the project team to include a broader range of participants from the community.

Technical Metrics and Scoring

Definition of "Technical Metrics and Scoring"

> "'Technical' aspects of rating systems include *how* we measure—the actual metrics and scoring system. Much has been written about technical aspects of rating systems—every international green building conference includes several papers comparing technical aspects of various rating systems…Current rating systems consist of discrete criteria that measure specific aspects of building design, construction or operation. Encouraging the evolution of rating systems to address broader context and expanded scope, including impacts on larger systems, will require different metrics" [8].

Over the past decade, the metrics used to measure specific elements of green buildings have evolved and become more robust, new standards and benchmarks are being developed, and data needed to support some of these metrics are becoming more available. There are many ways in which LEED metrics differ from those of many other rating systems. For example, most systems require scoring on all criteria while a few such as LEED allow projects to select the credits they will achieve; the metrics in some systems are measured on a scale (such as 1 to 5) to indicate achievement levels while most credits in LEED are "pass-fail;" some systems include explicit methods for weighting criteria according to importance while weighting in LEED is implicit, indicated by the number of points assigned.

"Technical Metrics and Scoring" in LEED Improvement

The USGBC's processes for developing, testing, and maintaining the technical aspects of LEED combine expert opinion, market experience, and member consensus. Technical Advisory Groups bring expertise in specific disciplines and Product Committees bring market experience and expertise. The consensus process ensures that LEED is fair, feasible, and likely to be used.

These processes can be no better than the knowledge that exists. Around the world and in the United States, efforts to develop better metrics have resulted in ideas for improving the way we measure specific aspects of buildings. In addition, better data are now available to enable us to apply available methods. Many of the LEED improvements will involve changes to the prerequisites and credits that reflect this new knowledge and data. A few examples are discussed below.

The USGBC initiated a process in 2004 to explore how environmental Life-Cycle Assessment (LCA) could be incorporated into LEED and the results of this effort will provide the foundation for developing LCA tools for LEED. LCA enables us to replace single attribute credits, such as recycled content, with credits that assess multiple environmental impacts across the entire life cycle of a product, thereby providing a more complete picture of which materials are environmentally preferable. Until recently, the United States lacked a publicly available database to support environmental Life-Cycle Assessments of building materials, but now a life-cycle database is under development with support from various government agencies and private industry.

Another technical improvement that is under consideration by the USGBC is "weighting;" that is, how much importance—or weight—is given to any specific credit or category of credits in LEED? Currently, LEED weighting is implicit and is reflected in the delineation of prerequisites and the number of points allotted to each credit. There is no explicit weighting of credit categories—Sustainable Sites, Energy and Atmosphere, Water Efficiency, Materials and Resources, and Indoor Environmental Quality. Weighting among categories can be viewed as the total number of possible credits assigned to each category, but some argue that since LEED credits are voluntary, this is quite different from a system in which all criteria are scored.

Another way of thinking about weighting is by environmental impact: How important is water consumption or climate change in LEED? Since LEED is not organized by impact, this would require an analysis of each LEED credit to determine its contribution to various impacts.

A third technical improvement included in LEED continuous improvement is incorporation of performance-based metrics and benchmarks. Like many other rating systems, much of LEED is based on prescriptive metrics. This would be expected in the rating system for new construction, but it also occurs in other versions of the rating system as well. The USGBC and users agree that measuring the actual performance of buildings is critical. The USGBC is analyzing the most current measurement methods from around the world to identify potential metrics for use in LEED as well as engaging experts on LEED committees to develop new metrics.

In addition, in the future, the USGBC will ask projects certified under LEED to commit to submitting actual performance data on energy and water consumption at one and two years after full occupancy. Additional data might be added as metrics are identified. This information will be kept anonymous at projects' request.

Process

Definition of "Process"

> "'Process' aspects of rating systems involve *making it happen*. This applies both to the rating systems themselves, and to the use of the rating system by project teams, building owners, and others" [9].

There are many "processes" that need to be considered. Sponsors of rating systems need to examine the processes used in their operations to design, implement, and administer the system. This includes questions of how the system is updated, how stakeholders are involved, how certifications are submitted and verified, what support is provided to users, and how results are communicated. Recently, sponsors of rating systems have been exploring other aspects of process. For example, how can rating systems encourage integrated design by project teams? How can rating systems encourage more meaningful dialog with communities affected by the project? How can rating systems communicate achievements more effectively and use this to educate and motivate markets? How can the rating tool be used in conjunction with other tools to be more effective?

"Process" in LEED Improvement

Improvements to the processes used to implement and administer LEED are a very important part of current USGBC efforts. These improvements focus on making the process more convenient and less burdensome for project teams, increasing the speed with which the USGBC and its committees can respond to issues or new ideas, and increasing the capacity of the USGBC to handle registrations, certification reviews, and the various activities that support LEED.

One change that will affect many LEED processes is transition of LEED from a series individual rating systems to a "bookshelf" or "library" of individual prerequisites and credits that can be assembled in different ways to create rating systems tailored to building types, stage of development, market segment, location, and perhaps other factors. By entering a few key pieces of information, a project team will receive a rating system that is tailored to be appropriate for that project. The prerequisites and credits will be modified as needed to make them most effective in meeting the objective stated in the intents in various contexts. In some cases, the modification will involve the method of measurement and documentation required—from modeled or estimated performance in a new building to actual performance in an operating building. In other cases, some credits might not be relevant to a stage of development—some site selection criteria for an operating building and some cleaning and maintenance criteria for new building design and construction. The more closely the prerequisites and credits can relate to the specific context of each project, the more effective they will be in achieving environmental improvements.

Use of the bookshelf approach will also enable the USGBC to operate LEED more efficiently. For example, prerequisites and credits can be updated individually to respond to new information and measurement methods or to relate to new building types and contexts. This will enable the USGBC to keep LEED more closely aligned with the organization's evolving goals and vision and to the needs of LEED users.

Conclusions

Application of the Framework to the LEED improvement effort has yielded several insights. First, the LEED improvement process is addressing all aspects of the framework, not just technical metrics or procedural improvements. It is examining everything from fundamental goals to details of credits or processes. Second, there are challenges awaiting LEED in each area that future improvements might address.

Acknowledgments

The authors wish to thank Scot Horst, 7Group and Chair of the LEED Steering Committee for the U.S. Green Building Council for his review and comments.

References

[1] Boecker, J., Todd, J. A., Reed, B., Malin, N., and Lindsey, G., “Seeing Beyond the Metrics: Lessons Learned from BGTool and Other International Systems,” U.S. General Services Administration, Washington, DC, August 2006.

[2] Boecker, J., Todd, J. A., Reed, B., Malin, N., and Lindsey, G., “Seeing Beyond the Metrics: Lessons Learned from BGTool and Other International Systems,” U.S. General Services Administration, Washington, DC, August 2006, pp. 3–4.

[3] Boecker, J., Todd, J. A., Reed, B., Malin, N., and Lindsey, G., “Seeing Beyond the Metrics: Lessons Learned from BGTool and Other International Systems,” U.S. General Services Administration, Washington, DC, August 2006, p. 2.

[4] See Cole, R. J., “Building Environmental Assessment Methods: Redefining Intentions,” Sustainable Building 2005, September 2005, Tokyo, Japan.

[5] Boecker, J., Todd, J. A., Reed, B., Malin, N., and Lindsey, G., “Seeing Beyond the Metrics: Lessons Learned from BGTool and Other International Systems,” U.S. General Services Administration, Washington, DC, August 2006, pp. 4–5.

[6] Boecker, J., Todd, J. A., Reed, B., Malin, N., and Lindsey, G., “Seeing Beyond the Metrics: Lessons Learned from BGTool and Other International Systems,” U.S. General Services Administration, Washington, DC, August 2006, pp. 5–6.

[7] Boecker, J., Todd, J. A., Reed, B., Malin, N., and Lindsey, G., “Seeing Beyond the Metrics: Lessons Learned from BGTool and Other International Systems,” U.S. General Services Administration, Washington, DC, August 2006, p. 8.

[8] Boecker, J., Todd, J. A., Reed, B., Malin, N., and Lindsey, G., “Seeing Beyond the Metrics: Lessons Learned from BGTool and Other International Systems,” U.S. General Services Administration, Washington, DC, August 2006, p. 9.

[9] Boecker, J., Todd, J. A., Reed, B., Malin, N., and Lindsey, G., “Seeing Beyond the Metrics: Lessons Learned from BGTool and Other International Systems,” U.S. General Services Administration, Washington, DC, August 2006, p. 11.

Journal of ASTM International, Vol. 4, No. 7
Paper ID JAI101065
Available online at www.astm.org

Richard N. Wright[1]

Practice, Education and Research for Sustainable Infrastructure (PERSI)

ABSTRACT: Practice, Education and Research for Sustainable Infrastructure (PERSI) is an initiative of the U.S. infrastructure community. PERSI seeks to advance and incorporate concepts and knowledge of sustainability into the standards and practices used throughout the life cycle of infrastructure systems. PERSI will not itself produce standards and practices, but will help ASTM and its other member organizations address sustainability consistently in their practices and standards. PERSI's immediate objectives are to assess current practices and standards and develop agendas for: 1. Implementation of best available practices; 2. Development of improved practices to exploit available knowledge; 3. Research to fill important gaps in knowledge; 4. Education of current and future infrastructure professionals and technicians. Proposed techniques for assessment of practices use whole life-cycle approaches to address environmental, economic, and social aspects of sustainability. These approaches have been widely used and standardized for assessments of environmental and economic sustainability of building materials and components. The scope of the assessment is broad in order to identify the most significant opportunities to improve the sustainability of infrastructure. The scopes of the agendas will be focused on these most significant opportunities.

KEYWORDS: education, infrastructure, practice, research, sustainable

Introduction

Sustainable infrastructure is essential to a sustainable society. Growth in human population and economic development strain the world's finite resources such as land, water, food, and energy. To maintain and improve quality of life we need sustainable development—development that meets human needs for natural resources, industrial products, energy, food, transportation, shelter, and waste management while conserving and protecting environmental quality (indoor and outdoor) and the natural, economic, and social resources essential for future development.

Infrastructure includes constructed facilities and natural features that shelter and support human activities: buildings of all types, communications, energy generation and distribution, green spaces, transportation of all modes, water resources, and waste treatment. Infrastructure is vital socially and economically: in the U.S., new construction and renovation of infrastructure amounts to about 1/8 of the Gross Domestic Product. To achieve sustainable infrastructure we need to use appropriate practices for its planning, design, construction, operation, maintenance, and renewal or removal.

Practice, Education and Research for Sustainable Infrastructure (PERSI) is an initiative of the U.S. infrastructure community. Participants to date include:

- American Institute of Architects
- American Institute of Chemical Engineers
- American Planning Association
- American Society of Civil Engineers
- American Society of Heating, Refrigerating and Air-Conditioning Engineers
- American Society of Interior Designers
- American Society of Landscape Architects
- American Society of Mechanical Engineers
- ASTM International
- American Water Works Association
- Autodesk

Manuscript received February 20, 2007; accepted for publication June 18, 2007; published online August 2007.
[1] PERSI, 20081 Doolittle St., Montgomery Village, MD, 20886.

- Congress for the New Urbanism
- Construction Specifications Institute
- Institute of Electrical and Electronics Engineers;
- National Institute of Building Sciences
- National Institute of Standards and Technology
- U.S. Green Building Council.

Participation is open to all organizations that produce, use, research for, or educate for practices for infrastructure, and are interested in the work of PERSI.

PERSI's vision is that sustainable infrastructure supports a high and sustainable quality of life for all people in a changing world. PERSI's mission is to advance and incorporate concepts and knowledge of sustainability into the standards and practices used throughout the life cycle of infrastructure systems. PERSI will not itself produce standards and practices, but will help its member organizations address sustainability consistently in their practices and standards.

PERSI's ultimate objectives are to:

1. Provide the practices needed for sustainable renewal of America's infrastructure to respond to marketplace values and meet society's needs.
2. Embed sustainability provisions in the practices regularly used for planning, design, construction, commissioning, operation, maintenance, renovation, and removal of infrastructure.
3. Assist educational programs in architecture, construction, engineering, planning, and related technologies, in incorporating principles for sustainable infrastructure in their curricula, and strengthen K–12 education to improve public understanding of sustainability and infrastructure, and to attract qualified youth to infrastructure careers.
4. Establish an enduring program of research to provide critically needed knowledge for improvement of practices for sustainable infrastructure.
5. Engage the U.S. infrastructure community in international efforts for sustainability.

PERSI's initial, technical objectives are to assess current practices and knowledge and develop agendas for:

1. Implementation of best available practices
2. Development of improved practices to exploit available knowledge
3. Research to fill important gaps in knowledge
4. Education of current and future infrastructure professionals and technicians

PERSI will complement, and build upon, important ongoing activities related to sustainable infrastructure such as green and sustainable building guidelines and practices for protection from natural, willful, and accidental hazards. PERSI's scope is novel in four respects: (1) it includes all standards and practices used in the life cycle of all infrastructure systems from urban and regional planning, which integrates infrastructure systems, to those for constituent materials and components and for operation and maintenance; (2) it involves the private sector organizations that produce and maintain the practices used for infrastructure systems and whose members implement these practices; (3) it will use rigorous life-cycle assessment and other procedures to provide consistent indicators of environmental, economic and social effects; and (4) it will produce agendas for implementation of best practices, improvement of practices to exploit available knowledge, research needed to fill critical gaps in knowledge, and education for infrastructure professionals and technicians.

Background

PERSI began in 2004 in the American Society of Civil Engineers' (ASCE) Committee on Sustainability, which is chaired by Albert Grant, past president of ASCE. The Committee reviewed policies and practices for sustainability to prepare, as a guide for young engineers, ASCE's *Sustainable Engineering Practice: An Introduction* [1]. The Committee then organized in February 2005, the Forum on Technical Opportunities for Sustainable Infrastructure [2] to initiate planning of PERSI to develop the practices needed for sustainable renewal of America's infrastructure. Participants represented all of ASCE's seven institutes, five of its divisions, councils, and committees, the Environmental Protection Agency, and the National Institute of Standards and Technology. The Forum recognized that PERSI should include other organizations with important roles in practice, education, and research for sustainable infrastructure. Dennis Martenson, ASCE President for 2005–2006, selected PERSI as an ASCE Presidential Initiative.

Subsequently, PERSI has involved seventeen organizations, organized its Technical Committee and produced, in 2006, its *Proposed Plan for the Assessment of Knowledge and Practice for Sustainable Infrastructure* [3]. Work is proceeding to fund and implement the Plan.

PERSI's technical approach has been guided by earlier British and international studies. The Civil Engineering Environmental Quality and Assessment Scheme (CEEQUAL), has been developed in the United Kingdom by a team led by the Institution of Civil Engineers, as a proprietary assessment and award scheme for publicly recognizing high environmental quality in civil engineering projects [4]. CEEQUAL categories describe the scope of practices used in most infrastructure projects:

1. Project Environmental Management
2. Land Use
3. Landscape
4. Ecology and Biodiversity
5. Archeological and Cultural Heritage
6. Water Issues
7. Energy
8. Use of Materials
9. Waste
10. Transport
11. Nuisance to Neighbors
12. Community Relations

The *Project Sustainability Management Guidelines* (PSM) [5] of the International Federation of Consulting Engineers describe a process for assuring that a project's goals for sustainable development address performance indicators traceable to goals and priorities that are recognized and accepted by society as a whole. The process also is designed to align goals with local conditions and priorities and to assist project owners and consulting engineers in achieving and verifying progress toward sustainable development.

PSM indicators are derived from the United Nations Division of Sustainable Development's *Indicators of Sustainable Development: Frameworks and Methodologies, 2001*, which in turn were based on *Agenda 21 Programme of Action for Sustainable Development* from the United Nations Conference on Environment and Development, Rio de Janiero, June 1992. The PSM indicators are clustered under Social, Environmental, and Economic dimensions. Examples of core project indicators are:

- Social 08: Record of safety performance during construction
- Environmental 03: Quantities of key air pollutants emitted in all phases of the project
- Economic 02: Extent of use of materials as compared to norms and other practices

Barabara Lippiatt of NIST has developed BEES (Building for Environmental and Economic Sustainability), as a rational, systematic technique for selecting environmentally-friendly, cost-effective effective building products [6] using life cycle assessment methods and multi-attribute decision making. It is based on consensus standards; designed to be practical, flexible, and transparent; uses the environmental life-cycle assessment approach specified in ISO 14040 standards; and is applicable, in principle, to the assessment of practices for infrastructure.

Performance Indicators

PERSI will use the performance approach to address the environmental, economic and social impacts of practices, rather than dealing prescriptively with characteristics of individual practices. Standard life-cycle approaches are available for environmental assessment from ISO environmental management standards (14040, 14041, 14042, and 14043) and for economic assessment from ASTM E 917-99, *Standard Practice for Measuring Life-Cycle Costs of Buildings and Building Systems.*

Performance indicators will be used rather than criteria, because (as with BEES) performance will be assessed rather than prescribed. However, practices and standards often establish criteria whose levels (corresponding to the indicators) describe the required performance.

Performance indicators should be selected with the following desirable characteristics in mind. Those indicators for which state-of-the-art science does not provide these characteristics will define topics for the PERSI research agenda.

- Traceability—measurement methods are tied to those documented in U.S. and/or international standards.
- Consistency—measurements are comparable to those developed for infrastructure systems and planning, for single infrastructure systems (e.g., green building) and related industries, and for other countries. Note that the consistency characteristic requires that scoping and boundary conditions (e.g., data requirements such as level of detail and geographic and time period coverage) be comparable. Furthermore, consistency might be considered one of the most important characteristics because it allows comparison of environmental impacts across performance indicators, industries, and even countries, which could help PERSI identify and prioritize the most significant sustainability issues associated with U.S. infrastructure projects.
- Transparency—measurements are documented in enough detail such that they may be replicated by a third party.
- Relevance—measurements address environmental performance, economic performance, and/or social performance, the three components of sustainability.
- Quality—the accuracy of measurements can be reported in quantitative terms (e.g., through uncertainty analysis results).
- Feasibility of use—measurements are relatively straightforward and understandable by a range of infrastructure professionals.
- Flexibility—measurement methods are adaptable to local conditions.
- Completeness—measurement methods neither double-count nor omit significant impacts related to sustainability.

Planned Approach

Developing the assessment and agendas involves:

1. Scoping task committees to carry out the study with an oversight committee (with a representative of each task committee) to coordinate the work. Within its scope, each task committee will:
    a. Establish its performance indicators based on available knowledge and traced, where possible, to established national, ISO, or UN indicators for sustainability.
    b. Review practices within its scope for the extent to which they address relevant performance indicators.
    c. Recommend "best practices" and agenda items for improvement of practices, research and education.
2. Commissioning a working paper for each task committee to support its work.
3. Holding a national workshop to critique task committee reports and develop consensus recommendations.

Planning and budgeting for developing the assessment and agendas require:

1. Defining the number and scopes of the task committees
2. Defining the technical approach for consistency among task committees
3. Identifying the expertise, timing and funding required for each task committee and for oversight and coordination of the work

The scope of the assessment is broad in order to identify the most significant opportunities to improve the sustainability of infrastructure. The agendas will be focused on these most significant opportunities.

Task Committee Structure

It is a major challenge to cover, with a manageable number of task committees, the practices needed for decisions for sustainability in all stages of the life cycles of all infrastructure systems. The experiences of CEEQUAL [4] and PSM [5] suggest that many practices at the project level are relevant to most infrastructure systems and can be covered with a modest number of project-level task committees. In addition to project level practices, there will be practices at the infrastructure system level unique to that system. An example might be a practice for identifying and developing the most sustainable sources for a water utility. Finally, there are topics of general relevance appropriate for task committees. Potential task committees and scope statements are shown below.

Project Level Task Committees

Project level task committees are based on some combinations of and elaborations on the CEEQUAL categories.

1. Project Environmental Management
   - Including environmental risk assessments considering conservation, restoration and remediation; active environmental management delivering environmental performance; training; and the influence of contracting and procurement processes.
   - Design for waste minimization, legal requirements, waste from site preparation, and on-site waste management.
   - Location of a project in relation to transport infrastructure, minimizing traffic impacts of a project, construction transport, and minimizing workforce travel.
   - Minimizing operation and construction-related nuisances, legal requirements, nuisance from construction noise and vibration, and from air and light pollution, and visual impact, including site tidiness, community consultation, community relations programs and their effectiveness, engagement with relevant local groups, and "joy in use."
2. Land Use, Landscape, Archeological and Cultural Heritage
   - Design for minimum land-take, legal requirements, flood risk, previous use of the site, contamination and remediation measures.
   - Consideration of landscape issues in design, amenity features, local character, loss and compensation or mitigation of landscape features, implementation and aftercare; and surveys, measures to be taken if archeological and cultural features are found, and information to the public and public access.
3. Ecology and Biodiversity—impacts on sites of high ecological value, protected species, conservation and enhancement, habitat creation measures, monitoring and maintenance.
4. Water and Air Issues—control of a project's impacts on, and protection of, the water and air environments.
5. Energy—life-cycle energy analysis, energy in use, and energy performance on site, but not embodied energy, which is covered under Use of Materials.
6. Use of Materials—minimizing environmental impact of materials used, optimizing material use and minimizing waste, specifying re-used and/or recycled material, minimizing use and impacts of hazardous materials, and providing for durability, maintenance, and future demolition.

Infrastructure Systems Level Task Committees

The following is a possible classification of infrastructure systems for the purpose of establishing task committees. For some, subcommittees may be needed (transportation systems issues are very different for ports and for pedestrians).

1. Buildings
   a. Residential
   b. Commercial
   c. Institutional
   d. Industrial
2. Transportation
   a. Highway
   b. Rail
   c. Airports
   d. Ports and waterways
   e. Pipelines
   f. Pedestrian and bicycle
3. Water Resources and Treatment
   a. Potable, agricultural, industrial and recreational water
   b. Waste water collection, treatment and recycling
   c. Storm water management
4. Solid Waste

   a. Collection
   b. Recycling
   c. Disposal
5. Energy
   a. Generation
   b. Distribution
6. Communications Physical Infrastructure
7. Flood and Storm Surge Control Systems including natural features such as barrier islands, deltas, and wetlands.
8. Global Warming Effects in Cold Regions

Task Committees of General Relevance

Four additional areas of practice seem relevant to all infrastructure systems and projects:

1. Measurements of Sustainability—including means for dealing with incommensurate environmental, social, and economic effects.
2. Planning for Sustainability—integrating infrastructure systems for sustainability at community, urban, and regional scales.
3. Geomatics for Sustainability—spatial and geographical information for sustainable decisions in planning, design, construction, operation, and maintenance.
4. Education for Sustainability—programs for continuing professional, post-graduate, undergraduate, public, and K–12 education to provide the motivation and knowledge base needed to achieve sustainable infrastructure.

Summary

(PERSI) is an initiative of the U.S. infrastructure community. PERSI seeks to advance and incorporate concepts and knowledge of sustainability into the standards and practices used throughout the life cycle of infrastructure systems. PERSI will not itself produce standards and practices, but will help its member organizations address sustainability consistently in their practices and standards

PERSI's immediate objectives are to assess current practices and standards and develop agendas for:

1. Implementation of best available practices
2. Development of improved practices to exploit available knowledge
3. Research to fill important gaps in knowledge
4. Education of current and future infrastructure professionals and technicians

Proposed techniques for assessment of practices use whole life-cycle approaches to address environmental, economic, and social aspects of sustainability. These approaches have been widely used and standardized for assessments of environmental and economic sustainability of building materials and components. The scope of the assessment is broad in order to identify the most significant opportunities to improve the sustainability of infrastructure. The scopes of the agendas will be focused on these most significant opportunities.

PERSI is initiating work of the task committees of general relevance on a volunteer basis and is seeking funding for conduct of the overall assessment of knowledge and practice for sustainable infrastructure.

References

[1] *Sustainable Engineering Practice: An Introduction*, J. A. Vanegas, Ed., Committee on Sustainability, American Society of Civil Engineers, Reston, VA, 2004.

[2] *Report of Forum on Technical Opportunities for Sustainable Infrastructure*, ASCE Committee on Sustainability, June 2005, see www.asce.org/files/pdf/instfound/june05report.pdf (June 11, 2007).

[3] *Proposed Plan for the Assessment of Knowledge and Practice for Sustainable Infrastructure*, PERSI Technical Committee, November 2006, see www.persi.us (June 4, 2007).

[4] *Civil Engineering Environmental Quality and Assessment Scheme*, see www.ceequal.com (February 17, 2007).

[5] *Project Sustainability Management Guidelines*, International Federation of Consulting Engineers, 2004, www1.fidic.org/bookshop/ (February 17, 2007).

[6] Lippiatt, B. C., *BEES 3.0, Building for Environmental and Economic Sustainability, Technical Manual and User Guide*, National Institute of Standards and Technology, Washington, DC, NISTIR 6916, 2002, www.bfrl.nist.gov/oae/software/bees.html (February 17, 2007).

NEXT STEPS

ASTM International announced the formation of ASTM Committee E60 on Sustainability.

The trend toward sustainability - achieving economic prosperity while protecting the natural systems of the planet - is an important issue confronting people and industries around the world. New environmental, social and economic challenges of recent years have heightened global awareness of sustainability even further. While both the public and private sectors have offered various programs that advance sustainability, widespread support is still lacking across mainstream markets.

Newly formed ASTM International Committee E60 will be the forum where diverse stakeholders come together to create the consensus standards that will promote and integrate sustainable development across multiple industry sectors.

ASTM Committee E60 will build upon the vast body of work of multiple ASTM technical committees who have developed standards that address various issues of sustainability. Notable among these is the efforts of ASTM Subcommittee E06.71 on Sustainability, which has contributed numerous standards that support sustainability in the building industry.

The ongoing activities of E06.71, including a newly formed task group on Green Meetings and Events, will now be coordinated by Committee E60. The initial scope of Committee E60 will be driven by subcommittees on Building and Construction, Hospitality and General Sustainability Standards. E60 will also support and serve as a resource for other ASTM committees in their activities that include sustainability issues.

For more information on this new technical committee, visit the Committee E60 Web page.

APPENDIX

First International Symposium on
Common Ground, Consensus Building and Continual Improvement:
Standards and Sustainable Building
April 19-20, 2007
AED Conference Center—Dupont Circle, Washington, DC
http://www.astm.org/MEETINGS/COMMIT/e06symp.htm

Sponsored by ASTM Committee E6 on Performance of Buildings and its Subcommittee E06.71 on Sustainability in cooperation with the US Environmental Protection Agency and the Office of the Federal Environmental Executive

Symposium Chairs:

Dru Meadows
theGreenTeam, Inc.
dmeadows@thegreenteaminc.com
tel: 918-295-8326

Alison Kinn Bennett
U.S. EPA
kinn.alison@epa.gov
tel: 202-564-8859

THURSDAY, APRIL 19, 2007
DAY 1—PRODUCTS

7:30–9:00 AM Registration and Continental Breakfast

9:00 AM **Opening Remarks;**
Dru Meadows and Alison Kinn Bennett, Symposium Co-Chairs
Edwin Piñero, the Federal Environmental Executive

9:30 **"An International Standard for Environmental Communication"**
Gary Wilson, Kleinfelder, Inc.

10:00 **"Type I Eco-Labels: Use and Misuse in Sustainable Building"**
Susan Herbert, TerraChoice Environmental Marketing Inc.
Scott McDougall, TerraChoice Environmental Marketing Inc

10:30 BREAK

10:45 **"Developing / Driving Environmentally Preferable & Sustainable Product Standards into the Market"**
Kirsten Ritchie, Gensler

11:15 **"Data Standards That Support Sustainable Buildings and Procurement"**
Gregory Norris, Sylvatica

11:45 **"The Label Game"**
Bill Walsh, Healthy Building Network

12:15 LUNCH

1:00 **Federal Goals**
James Connaughton, Chairman, the White House Council on Environmental Quality

1:30	**"Responsible Purchasing Network—Identifying Environmental Purchasing Standards"** Dan Burgoyne, State of CA Dept of General Services Chris O'Brien, Center for a New American Dream
2:00	**"A Standard Developing Organization's Analysis of Low-Emitting Products Certification Programs—What does it take?"** Ben Taube, Greenguard Environmental Institute
2:30	**"IAQ standards and guidelines"** Ken Sandler, EPA
3:00	BREAK
3:15	**"Development of American National Standards for Sustainable Products"** Jane Wilson, NSF International Jaclyn Bowen, NSF International
3:45	**"Meeting Customer Demand with BIFMA's Sustainable Assessment Standard"** Bill Stough, Sustainable Research Group
4:15	**"Evaluating Sustainability Using Standard Approaches: The BEES Tool"** Barbara Lippiatt, National Institute of Standards & Technology

FRIDAY, APRIL 20, 2007
DAY 2—BUILDINGS

7:30–8:00 AM	**Continental Breakfast**
8:00	**Opening Remarks** **NIBS High Performance Building Council and EPACT Section 914** Earle Kennett, National Institute of Building Sciences (NIBS)
8:30	**"Sustainability in Building Construction General Principles ISO 15392"** Wolfram Trinius, Buro Trinius Christer Sjvstrvm, Centre for Built Environment
9:00	**"Building Systems for Introducing Standards and Sustainable Design"** William Kelly, Catholic University of America
9:45	**"Standards vs. Recommended Practice: Separating Process & Prescriptive Measures from Building Performance"** Wayne Trusty, Athena Institute
10:15	BREAK
10:30	**"Designing an Assessment System of Buildings for All Lifecycle Stages Based on the Concept of Eco-efficiency"** Junko Endo, Nikken Sekkei Research Institute Shuzo Murakami, Faculty of Science and Technology, Keio University Toshiharu Ikaga, Faculty of Science and Technology, Keio University
11:30	**"BRE Environmental Profiles—7 years' experience"** Kristian Steele, BRE
12:30	LUNCH

1:00	**"The New Normal—Green Building Systems"** Susan Herbert, TerraChoice Environmental Marketing Inc. Scott McDougall, TerraChoice Environmental Marketing Inc.
1:30	**"Development of a Canadian National Standard on Design for Disassembly and Adaptability"** Michael Clapham, Natural Resources Canada Simon Foo, Public Works and Government Services Canada Jabeen Quadir, Canadian Standards Association
2:00	**"The Review of Sustainability Building Standards in China"** Gang Liu, China Institute of Building Standard D&R;
3:00	**"Progress Report on ASHRAE/USGBC/IESNA 189, Standard for High-Performance, Green Buildings Except Low-Rise Residential Buildings"** John Hogan, City of Seattle DPD
3:30	BREAK
3:45	**"Continuous Improvement of the LEED Rating System"** Joel Ann Todd, Consultant Scott Horst, Horst, Inc. Tom Hicks, USGBC
4:15	**"GSA Review of Sustainable Building Rating Systems"** Donald Horn, GSA - Public Building Service
4:45	**"Practice, Education and Research for Sustainable Infrastructure (PERSI)"** Richard Wright, PERSI
5:15	**"Closing Remarks"** Dru Meadows and Alison Kinn Bennett, Symposium Co-Chairs

www.astm.org

ISBN: 978-0-8031-4507-8

Stock #: STP1503