# SCIENCE-BASED METRICS FOR PRODUCT SUSTAINABILITY ASSESSMENT

Barbara C. Lippiatt, Economist
National Institute of Standards and Technology*

**Abstract**
Consumers and manufacturers need compelling metrics, tools, and data supporting investments in sustainable products. Today's marketplace is fraught with sustainability claims that are often based on incomplete, anecdotal evidence that is difficult to reproduce and defend. The claims suffer from two main weaknesses: (1) products upon which claims are based are not necessarily "green" in a science-based, life-cycle assessment (LCA) sense and (2) their measures of cost-effectiveness often are not based on standard methods for measuring economic worth. The problem is hard to solve because methods, tools, and robust data for sustainability performance measurement are not widely available. The National Institute of Standards and Technology (NIST) is addressing these needs by developing rigorous metrics and tools for scientifically assessing the life-cycle economic and environmental performance of products. Economic performance is measured using standard life-cycle costing methods. Environmental performance is measured using LCA methods that assess the "carbon footprint" of products as well as 11 other sustainability metrics including fossil fuel depletion, smog, water use, habitat alteration, indoor air quality, and human health. These environmental and economic performance metrics are applied to assess the sustainability of 230 building products in the NIST Building for Environmental and Economic Sustainability (BEES) tool. The approach is illustrated with a BEES case study of five floor covering products.

## Introduction

An environmentally conscious consuming public is demanding products that are more sustainable. Manufacturers are seeking to meet the expectations of consumers and the demands of regulators while becoming more environmentally responsible. (1)(2) For consumers, regulators, and manufacturers alike, this requires that credible processes be implemented to accurately measure the environmental impacts of products.

Yet consumers are not willing to purchase environmentally sustainable products at any cost. The economic dimension of sustainability will always be a factor in purchasing decisions. However, while a given product might be either less or more costly than its competitor when purchased, what really matters is the cost comparison over the life of the product. Though more expensive to purchase, one product might well have a longer useful life and have lower maintenance and disposal costs than a competing product, thus offsetting a higher initial purchase price. Hence product costs measured over a product's useful life provide the most appropriate measure of a product's economic sustainability.

This chapter focuses on the development of sustainability performance metrics to support sound decisions by industry and consumers in the selection and use of sustainable products. These metrics consider both the environmental and economic dimensions of sustainability. They are based on sound science that is translated into performance scores that can be understood by scientists and non-scientists alike, thus providing useful information to inform product selection decisions.

**Background**

The National Institute of Standards and Technology (NIST), an agency of the U.S. Department of Commerce, is the U.S. national measurement institute. NIST develops unbiased, state-of-the-art measurement science that advances the nation's technology infrastructure and is needed by industry to continually improve products and services. With this mission in mind, the agency began the Building for Environmental and Economic Sustainability (BEES) program in 1994, with the goal of developing a rational, systematic technique for selecting environmentally preferred, cost-effective products. The BEES software, which applies the technique to 230 building products, is in widespread use today, with nearly 30,000 users in over 80 countries. (3)

The BEES approach attracted the attention of the U.S. Environmental Protection Agency's Environmentally Preferable Purchasing (EPP) Program in 1997. With EPP support, the tool was further developed and recommended by EPP for cost-effective, environmentally preferable federal purchasing. Since 2002, NIST has further developed BEES in support of the USDA BioPreferred Program, a preferred purchasing program established by the 2002 Farm Bill that requires BEES performance evaluation. (2)

**Objectives**

The BEES analytical technique takes a multidimensional, life cycle approach. That is, it considers multiple environmental and economic impacts over the entire life of a product. Considering multiple impacts and life cycle stages is necessary because product selection decisions based on single impacts or stages could obscure other impacts or stages that might cause equal or greater damage. In other words, a multidimensional approach is necessary for a comprehensive, balanced analysis of environmental and economic impact.

It is relatively straightforward to select products based on minimum life cycle economic impacts because products are bought and sold in the marketplace. But how does one consider environmental impacts in purchase decisions? Impacts such as global warming, 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 economic terms. How does one put a price on clean air and clean water? What is the value of human life? Economists have debated these questions for decades, and consensus does not appear likely.

While environmental performance cannot be measured on a monetary scale, it can be quantified using the multi-disciplinary approach known as LCA. The BEES approach measures environmental performance using an LCA approach, following guidance in the International Organization for Standardization (ISO) 14040 standard for LCA. (4) An ASTM International standard for Multi-Attribute Decision Analysis also is followed in order to synthesize LCA results across multiple impacts into a single, decision-enabling environmental performance score. (5) Economic performance is separately measured using the ASTM International standard life cycle cost (LCC) approach. (6)

Environmental life cycle assessment is a "cradle-to-grave," systems approach for measuring environmental performance. The approach is based on the belief that all stages in the life of a product generate environmental impacts and must therefore be analyzed, including raw materials acquisition, product manufacture, transportation, use, and ultimately waste management. An 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 scope. Many environmental claims and strategies today are based on a single life cycle stage or a single environmental impact. A product is claimed to be "green" because it has recycled or biobased content, or criticized of not being green because its manufacture contributes to air pollution. These single-attribute claims may be misleading because they ignore the possibility that other life cycle stages, or other environmental impacts, may yield offsetting impacts. For example, an LCA for a recycled content product will account for replacement of raw materials with recycled inputs, meaning there are no longer environmental burdens associated with the replaced raw materials. Yet recycled inputs are not burden-free, so the LCA will now include *other* burdens—those associated with collection, transportation, and processing of the recycled input into a form suitable for product production. Whether the old burdens are worse than the new ones cannot be assumed a priori: The replaced material may be quite benign, while the recycled content product may have high embodied energy content, leading to fossil fuel 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 impacts from one life cycle stage to another, or one environmental medium (land, air, water) to another. The benefit of the LCA approach is in implementing a tradeoff analysis to achieve a genuine reduction in overall environmental impact, rather than a simple shift of impact.

## Description of Work

***Environmental Performance Measurement***. The general LCA methodology involves four steps. The *goal and scope definition* step spells out the purpose of the analysis 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. As shown in Figure 1, environmental inputs include use of materials, fuel, water, land, and other resources; outputs include releases to air, land, and water. However, it is not these inputs and outputs, or *inventory flows*, which are of primary interest. Of more interest are 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, the impact assessment step 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.

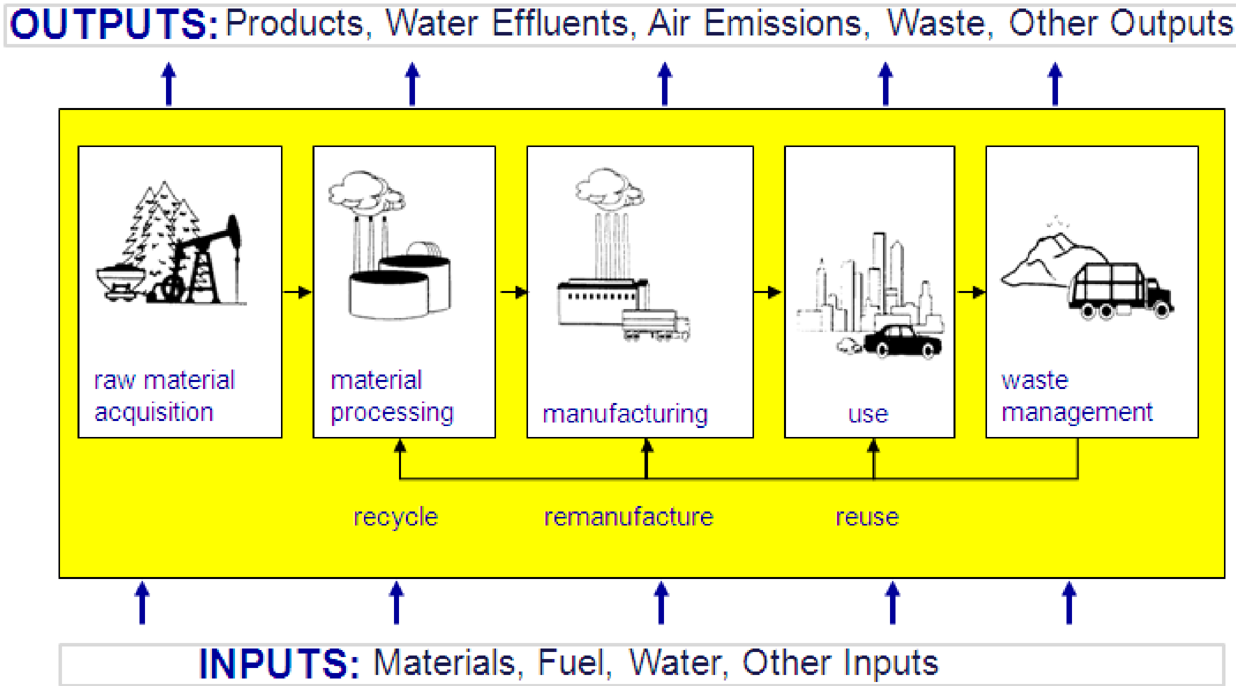


Figure 1. Framework for Life Cycle Inventory Analysis

While this chapter focuses primarily on the BEES life cycle impact assessment and interpretation approaches, it is important to note that rigorous, consistent life cycle scoping and inventory analysis are critical for credible LCAs. For example, the BEES goal and scoping phase sets consistent boundaries for all product systems under study, whereby all life cycle industrial processes that meet either mass or energy contribution criteria are included in the analysis. Some additional processes are included based on their cost contribution, even if they do not meet established mass or energy criteria, because a significant cost may indicate scarce natural resources or numerous subsidiary industrial processes potentially involving high energy consumption. For more on BEES' consistent scoping and inventory analysis criteria, refer to the BEES technical documentation. (3)

The impact assessment step of LCA quantifies the potential contribution of a product's inventory flows to a range of environmental impacts. There are several well-known LCA impact assessment approaches:

*Direct Use of Inventories*. In the most straightforward approach to LCA, the impact assessment step is skipped, and the life cycle inventory results are used as-is in the final interpretation step to help identify opportunities for pollution prevention or increases in material and energy efficiency for processes within the life cycle. However, this approach in effect gives the same weight to all inventory flows (e.g., carbon dioxide emissions and lead releases). For most products, equal weighting of flows is unrealistic.

*Ecological Scarcity (Switzerland).* With this approach, "Eco-Points" are calculated for a product, using the "Eco-Factor" determined for each inventory flow. (7) Eco-Factors are based on current annual flows relative to target maximum annual flows for the geographic area considered. The Eco-Points for all inventory flows are added together to give one single, final measure of impact. While appealing, the concept has a number of difficulties, such as being valid only in a specific geographical area, problems in estimating target flows, and that the scientific calculation of environmental impacts is inextricably combined with political and subjective judgment. The preferred approach is to separate the life cycle impact and interpretation steps.

*Environmental Priorities System (Sweden)***.** The Environmental Priority Strategies in Product Development System, the EPS System, takes an economic approach to assessing environmental impacts. (8) The basis for the evaluation is the Environmental Load Unit, which corresponds to the willingness to pay 1 European Currency Unit. The final result of the EPS system is a single number summarizing all environmental impacts, based on society's judgment of the importance of each environmental impact, its intensity, frequency, location and timing, the contribution of each flow to the impact, and the cost of decreasing each inventory flow by one weight unit. Although this methodology is popular in Sweden, its use is criticized due to its lack of transparency and the quantity and quality of the model's underlying assumptions.

***Eco-Indicator 99/ ReCiPe.*** The Eco-Indicator 99 method is a “damage-oriented” approach to life cycle impact assessment developed in The Netherlands. (9) It is appealing for its emphasis on simplifying the subsequent life cycle assessment step, namely, the weighting of the relative importance of environmental impacts. To this end, a very limited number of environmental damage categories, or “endpoints,” are evaluated: Human Health, Ecosystem Quality, and Resources. Damage models are used to evaluate products in relation to these three damage categories. While the Eco-Indicator 99 method offers promise for the future—and recently has been updated and repackaged into the ReCiPe method—it continues to be criticized for the many scientific assessment gaps in the underlying damage models. (10)

*Environmental Problems*. The Environmental Problems approach to impact assessment was developed within the Society for Environmental Toxicology and Chemistry (SETAC). (11) It involves a two-step process:

- 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.
- 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, which 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 greenhouse gas in terms of its equivalent amount of carbon dioxide heat trapping potential.

The Environmental Problems approach does not offer the same degree of relevance for all environmental impacts. For global and regional effects (e.g., global warming and acidification) the method provides an accurate description of the potential impact. For impacts dependent upon local conditions (e.g., smog), it may result in an oversimplification of the actual impacts because the indices are not tailored to localities.

The Environmental Problems approach is preferred by most LCA practitioners and scientists today. For this reason, BEES uses the approach where possible. 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. (12) Ten of the 11 TRACI 1.0 impacts follow the Environmental Problems approach: Global Warming Potential, Acidification Potential, Eutrophication Potential (a water pollution indicator), Fossil Fuel Depletion, Habitat Alteration/Land Use, Criteria Air Pollutants, Human Health, Smog, Ozone Depletion, and Ecological Toxicity. Water Use is assessed in TRACI 1.0 using the Direct Use of Inventories Approach, as is Indoor Air Quality, the $12^{th}$ and final BEES impact. For more on the 12 BEES environmental impacts, refer to the BEES technical documentation. (3)

At the LCA interpretation step, the normalized impact assessment results are evaluated. Few products are likely to dominate competing products in all BEES impact categories. Rather, one product may out-perform the competition relative to fossil fuel depletion and habitat alteration, fall short relative to global warming and acidification, and fall somewhere in the middle relative to indoor air quality and eutrophication. To compare the overall environmental performance of competing products, the performance scores for all impact categories may be synthesized. Note that in the BEES 4.0 software, synthesis of impact scores is optional.

Impact scores may be synthesized by weighting each impact category by its relative importance to overall environmental performance, then computing the weighted average impact score. In the BEES software, the set of importance weights is selected by the user. Several alternative weight sets are provided as guidance, and may be either used directly or as a starting point for developing user-defined weights. The alternative weights sets are based on an EPA Science Advisory Board study, a 2006 BEES Stakeholder Panel's structured judgments, and a set of equal weights, representing a spectrum of ways in which people value diverse aspects of the environment. (13)

To simplify decisionmaking and facilitate purchasing, BEES summarizes life cycle environmental performance results as single scores based on the selected weight set. For the sake of transparency and to highlight the underlying tradeoffs among and within impacts, BEES also reports the contribution of each individual environmental impact to this score, as well as the contribution of each individual environmental flow to each individual environmental impact.

***Economic Performance Measurement.*** BEES measures a product's economic performance using the ASTM International life cycle cost (LCC) method. (6) Economic performance is evaluated over a fixed period (known as the study period) that begins with the purchase of the product and ends at some point in the future. Over this period, the LCC method evaluates both "first costs" and "future costs." For consumable products for which future costs are irrelevant, the study period is set at zero and economic performance is measured on a first cost basis alone. For durable products such as equipment and building products, the LCC study period length depends upon the decision maker. For a private investor, its length is set at the period of product ownership. For society as a whole, the study period length is often set at the useful life of the longest-lived alternative in a product category.

The same study period length is used to evaluate all products in a category to account for the fact that different products have different useful lives. BEES takes the societal perspective, setting the study period length for most durable products at the useful life of the longest-lived alternative. If an alternative lasts more than 50 years, however, the study period is limited to 50 years because technological obsolescence becomes an issue, data become too uncertain, and the farther in the future, the less important the costs. The BEES study period for building products is set at 50 years.

The LCC method sums over the study period all relevant costs associated with a product. Alternative products for the same functional product category, say floor covering, can then be compared on the basis of their LCCs to determine which is the least cost means of fulfilling that function over the study period. Categories of cost typically include costs for purchase, installation, operation, maintenance, repair, replacement, and disposal. A negative cost item is the residual value, or the product value remaining at the end of the study period.

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 (e.g., 2007) costs. Real discount rates reflect that 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 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. BEES computes LCCs using constant year dollars and that year's prevailing real discount rate (3% in 2007) mandated by the U.S. Office of Management and Budget for most Federal analyses. (14)

## Results and Analysis

The following figures and table illustrate the output from a BEES 4.0 analysis of environmental impacts and life-cycle costs of five selected floor coverings. The environmental impact scores and life-cycle costs for ceramic tile with recycled glass content, linoleum flooring, terrazzo, nylon carpet tile, and nylon broadloom carpet are presented in Figure 2. Values are given on an equivalent functional unit basis: covering one square foot of floor surface over 50 years of use (including product replacements and disposal). The lower the values, the more preferable the product would be from an environmental and cost perspective.

The Raw Results for potential environmental impacts are expressed in physical units appropriate for the impact.[1] In order to synthesize these results into a single

[1] Following are more complete descriptions of environmental impact units: Acidification: millimoles of hydrogen ion equivalents; Criteria Air Pollutants: micro Disability-Adjusted Life Years; Ecological Toxicity:

environmental performance score for each floor covering, raw results are weighted (in this example approximately equally) and normalized by reference to each impact's annual per capita performance at the U.S. level. Note that while quantifying the uncertainty surrounding BEES results is an important future research direction, the underlying impact assessment models at present preclude such quantification.

| Potential Environmental Impact | Raw Results* Units | Tile/Glass | Linoleum | Terrazzo | NylonTile | NylonBrdlm | *Weighting (%)* Equal | Normalized Results** Tile/Glass | Linoleum | Terrazzo | NylonTile | NylonBrdlm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Acidification | mg H+ | 9.62e+02 | 6.07e+02 | 1.25e+03 | 2.09e+03 | 2.19e+03 | 9 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Criteria Air Pollutants | microDALY | 2.83e-01 | 1.42e-01 | 4.14e-01 | 6.47e-01 | 6.73e-01 | 8 | 0.0001 | 0.0001 | 0.0002 | 0.0003 | 0.0003 |
| Ecological Toxicity | g 2,4-D | 8.48e+00 | 7.38e+00 | 7.19e+00 | 1.35e+01 | 8.69e+00 | 8 | 0.0008 | 0.0007 | 0.0007 | 0.0013 | 0.0009 |
| Eutrophication | g N | 4.40e-01 | 2.17e+00 | 1.46e+00 | 4.13e+00 | 6.55e+00 | 9 | 0.0002 | 0.0010 | 0.0007 | 0.0019 | 0.0031 |
| Fossil Fuel Depletion | MJ | 4.19e+00 | 2.42e+00 | 6.54e+00 | 1.37e+01 | 1.69e+01 | 9 | 0.0011 | 0.0006 | 0.0017 | 0.0035 | 0.0043 |
| Global Warming | g CO2 | 2.51e+03 | 1.33e+03 | 2.67e+03 | 5.21e+03 | 6.00e+03 | 9 | 0.0009 | 0.0005 | 0.0009 | 0.0018 | 0.0021 |
| Habitat Alteration | T&E | 0.00e+00 | 0.00e+00 | 0.00e+00 | 0.00e+00 | 0.00e+00 | 8 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Indoor Air Quality | g VOC | 3.70e-02 | 1.20e-01 | 0.00e+00 | 6.35e+00 | 5.48e+01 | 8 | 0.0000 | 0.0000 | 0.0000 | 0.0014 | 0.0125 |
| Ozone Depletion | gCFC-11 | 0.00e+00 | 0.00e+00 | 0.00e+00 | 0.00e+00 | 0.00e+00 | 8 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Smog | g NOx | 1.31e+01 | 1.20e+01 | 2.03e+01 | 2.64e+01 | 3.02e+01 | 8 | 0.0007 | 0.0006 | 0.0011 | 0.0014 | 0.0016 |
| Water Intake | liter | 1.51e+01 | 4.46e+01 | 9.52e+01 | 2.24e+02 | 4.21e+02 | 8 | 0.0002 | 0.0007 | 0.0014 | 0.0034 | 0.0064 |
| Human Health--All | g C7H8 | 5.05e+05 | 1.92e+04 | 3.99e+04 | 3.12e+05 | 8.73e+04 | 8 | 0.0147 | 0.0006 | 0.0012 | 0.0091 | 0.0025 |
| Health--Cancer | | | | | | | | | | | | |
| | | | | | | | **Total** | 0.0187 | 0.0048 | 0.0079 | 0.0241 | 0.0337 |

**Expressed in penalty points per functional unit of product

| Economic Impact | Units | Tile/Glass | Linoleum | Terrazzo | NylonTile | NylonBrdlm |
|---|---|---|---|---|---|---|
| First Cost | $ | 9.55 | 3.56 | 23.59 | 3.58 | 2.13 |
| Future Cost | PV$ | 0.00 | 1.20 | 0.00 | 4.18 | 3.81 |
| **Life-Cycle Cost** | | 9.55 | 4.76 | 23.59 | 7.76 | 5.94 |
| ***Discount Rate (%)*** | | 3.0 | | | | |

**Note: Lower values are better**

*Expressed in given impact units per functional unit of product

*Change Parameters*

Figure 2. BEES Results Summary: Five Selected Floor Coverings

As shown, life-cycle costs range from $4.76 to $23.59 (in present value dollars) per square foot over 50 years. The total environmental performance scores range from 0.0048 to 0.0337 penalty points per square foot over 50 years, and are displayed graphically in Figure 3. These quantitative performance scores permit a customer to evaluate the overall life-cycle impacts of a product and also enable an evaluation of the product on a measure-by-measure basis.

grams of 2,4-dichlorophenoxy-acetic acid equivalents; Eutrophication: grams of nitrogen equivalents; Fossil Fuel Depletion: megajoules of surplus energy; Global Warming: grams of carbon dioxide equivalents; Habitat Alteration: threatened and endangered species count; Indoor Air Quality: grams of Total Volatile Organic Compounds; Ozone Depletion: grams of chloroflourocarbon-11 equivalents; Smog: grams of nitrogen oxide equivalents; Water Intake: liters of water; and Human Health: grams of toluene equivalents.

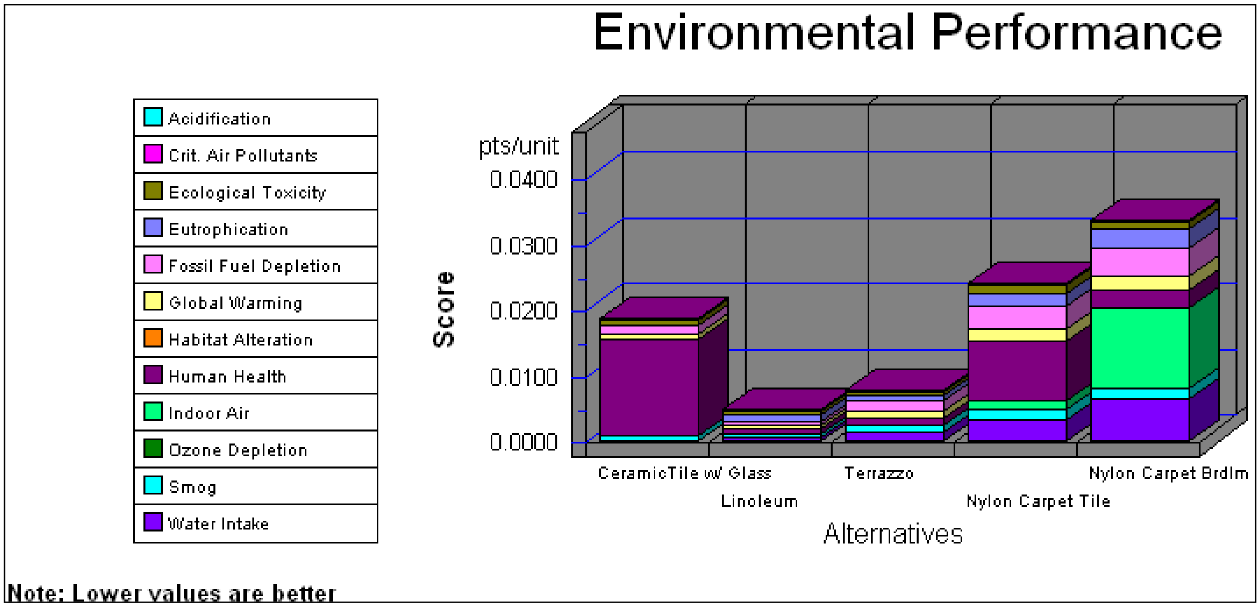


Figure 3. BEES Environmental Performance Scores for Five Selected Floor Coverings

Use of the BEES approach adds value to consumer purchase decisions for several reasons. First, BEES development and analysis by the National Institute of Standards and Technology, a non-regulatory federal agency known for developing unbiased world-class measurement science, lends integrity to the results. Second, BEES is internally consistent with respect to underlying life cycle costing, scoping, inventory analysis, impact assessment, and interpretation criteria, permitting fair comparisons among products. Finally, BEES' use of consensus standard guidance for life cycle environmental and economic impact assessment facilitates industry acceptance of the approach.

Taken together, BEES' integrity, internal consistency, and results comparability promote technological innovation. Its use of a performance-based approach—one that accounts for inevitable tradeoffs among the many dimensions of life cycle environmental and economic performance, rather than one prescribing arbitrary performance thresholds on an impact-by-impact basis—levels the playing field for industry and promotes competition on a meaningful basis. In the short run, performance-based measures enable meaningful improvement by manufacturers in emerging industries by pinpointing weak links in their products' life cycles (e.g., process efficiencies, transportation distances). In the long run, performance-based measurements are essential for technological innovation. If consumers were to judge environmental performance solely on the basis of a single-attribute prescriptive requirement—say, biobased content—manufacturers would be motivated to find the least-cost means of maximizing biobased content. Some may accomplish this through inferior performance on other important attributes. Prescriptive requirements inhibit innovation by restricting the choices available to manufacturers. The BEES performance-based measures, on the other hand, give manufacturers the freedom to develop products that can compete on the basis of best value, which is critical to a sustainable economy.

BEES must remain flexible to keep pace with advances in measurement science. Life cycle impact assessment is evolving. While BEES incorporates state-of-the-art impact assessment methods today, the science will continue to evolve and methods now in use—particularly those for land use, water intake, and human health—are likely to change and improve over time. Future versions of BEES should incorporate these improved methods as they become available.

As science advances, so will the relative importance society places on environmental impacts. BEES uses such importance weights to synthesize its 12 environmental impact scores into a single decision-enabling score. Similarly, the U.S. Office of Management and Budget issues annual updates to its discount rates to account for changes in the real earning power of the dollar over time. BEES uses these discount rates in its life cycle economic performance scoring to convert future costs to their equivalent present value. As both society's tradeoffs and the dollar's earning power change over time, BEES should incorporate these values in a systematic manner; one that preserves comparability among BEES results while at the same time accommodating inevitable change.

**Conclusions**

U. S. consumers are increasingly demanding sustainable products in the marketplace. However, too often the environmental and economic performance of products marketed as "sustainable" have not been well documented on a quantitative life-cycle basis. Considering multiple impacts and life cycle stages is necessary because superior product performance on a single impact or stage may be achieved at the cost of exacerbating others. A multidimensional approach is necessary for a comprehensive, balanced analysis. Increasingly, policymakers and consumers are calling for quantitative, science-based analytical techniques to evaluate the life-cycle sustainability performance of products.

The analytical method discussed in this chapter represents significant progress in efforts to reliably evaluate the environmental and economic impacts of the production, use, and disposal of products. BEES establishes a scientifically supported set of quantitative measures for sustainability assessment. The program does not tell the consumer which product to purchase, but instead provides quantitative information that enables the user to responsibly weigh the relative merits of each product being considered. The analytical technique represents a conceptual breakthrough in evaluating such products on a cradle to grave basis, thus providing a much clearer understanding of overall sustainability performance and the underlying tradeoffs among its many dimensions.

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