BUILDING FOR ENVIRONMENTAL AND ECONOMIC SUSTAINABILITY (BEES): SOFTWARE FOR SELECTING COST-EFFECTIVE GREEN BUILDING PRODUCTS[1]

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ABSTRACT

The BEES (**B**uilding for **E**nvironmental and **E**conomic **S**ustainability) tool implements a rational, systematic technique for selecting cost-effective green building products. The technique is based on consensus standards and designed to be practical, flexible, and transparent. Version 2.0 of the Windows-based decision support software, aimed at designers, builders, and product manufacturers, is available free of charge and includes actual environmental and economic performance data for 65 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 the International Standards Organization (ISO) 14040 series of standards. The approach is based on the belief that all stages in the life of a product generate environmental impacts and must be analyzed. The stages include raw material acquisition, manufacture, transportation, installation, use, and waste management. Economic performance is measured using the American Society for Testing and Materials (ASTM) standard life-cycle cost method. The technique includes the costs over a given study period 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.

Applying the BEES approach leads to several general conclusions. First, environmental claims based on single attributes, such as recycling, should be viewed with skepticism. These claims do not account for the fact that other impacts may indeed cause equal or greater damage. Second, assessments must always be quantified on a functional unit basis, such that the products being compared are true substitutes for one another. Third, a product may contain a high-impact constituent, but if that constituent is a small portion of an otherwise benign product, its significance decreases dramatically. Finally, a short-lived, low first-cost product is often not the cost-effective alternative. In sum, the answers lie in the trade-offs.

The BEES methodology is being refined and expanded under sponsorship of the U.S. EPA Environmentally Preferable Purchasing (EPP) Program. The EPP program is charged with carrying out Executive Order 13101, "Greening the Government Through Waste Prevention, Recycling, and Federal Acquisition," which encourages Executive agencies to reduce the environmental burdens associated with the $200 billion in products and services they buy each year, including building products. BEES is being further developed as a tool to assist the Federal procurement community in carrying out the mandate of Executive Order 13101.

KEYWORDS:

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Economic performance, Environmental performance, Green buildings, Life cycle assessment, Life-cycle costing.

INTRODUCTION

How do *you* select environmentally preferable products? Designers and builders are increasingly asked to address the issue of "green" building materials. Is a product environmentally preferable if it has recycled content? Is it not preferable if it offgasses during use? Are mainstream products always less preferable than products marketed and perceived as "environmentally friendly?" Do environmentally preferable products always cost more? The BEES software says, "not necessarily."

A new version of the BEES software is now available for downloading at no charge (www.bfrl.nist.gov/oae/bees.html).[2] BEES (**B**uilding for **E**nvironmental and **E**conomic **S**ustainability) brings to your fingertips a powerful technique for selecting cost-effective, "green" building products. 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 and the White House-sponsored Partnership for Advancing Technology in Housing (PATH), the tool is based on consensus standards and designed to be practical, flexible, and transparent. Version 2.0 of the Windows™-based decision-support software--aimed at designers, builders, and product manufacturers--includes actual environmental and economic performance data for over 65 generic building products.

BEES METHODOLOGY

BEES measures the environmental performance of building products using the internationally-standardized and science-based life-cycle assessment approach (International Standards Organization, 1997; 1998; 2000). All stages in the life of a product are analyzed: raw material acquisition, manufacture, transportation, installation, use, and recycling and waste management. Up to ten environmental impacts are measured across these life-cycle stages: global warming, acid rain, resource depletion, indoor air quality, solid waste, eutrophication (the unwanted addition of mineral nutrients to the soil and water), ecological toxicity, human toxicity, ozone depletion, and smog. Due to its comprehensive, multi-dimensional scope, life-cycle assessment accounts for shifts of environmental problems from one life-cycle stage to another, or one environmental medium (land, air, or water) to another. The approach highlights the tradeoffs that must be made to genuinely reduce overall environmental impacts.

BEES measures economic performance using similar life-cycle thinking. Economic performance is measured using the ASTM standard life-cycle cost method, which covers the costs of initial investment, replacement, operation, maintenance and repair, and disposal (American Society for Testing and Materials, 1994). The life-cycle cost method sums these costs over a fixed period of time, known as the study period. Alternative products for the same function, say floor covering, can then be compared on the basis of their life-cycle costs to determine which is the least-cost means of covering the floor over the study period.

To combine environmental and economic performance into an overall performance measure, BEES uses the ASTM standard for Multiattribute Decision Analysis (American Society for Testing and Materials, 1995). 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. Supporting data and computations are documented.

[2] The BEES 2.0 Technical Manual and User Guide is also downloadable from the BEES web site. If you prefer a free BEES 2.0 compact disc and printed manual, place your order through the EPA Pollution Prevention Information Clearinghouse by calling (202) 260-1023 or e-mailing ppic@epamail.epa.gov.

CASE EXAMPLE

So how can *you* use BEES to compare the environmental and economic performance of competing products? Let's run through an example. Suppose we're considering three exterior wall finishes: (1) aluminum siding, (2) vinyl siding, and (3) cedar siding.

The first step is to set our analysis parameters using the BEES window shown in Figure 1. If we do not wish to combine environmental and economic performance measures into a single score, we can select the "No Weighting" option and still compute disaggregated BEES results. Otherwise, we need to set importance weights. In this example, environmental performance and economic performance are of equal importance so both are set to 50 %. Next, we need to set relative importance weights for the environmental impact categories included in the BEES environmental performance score. We select the "Equal Weights" set, assigning equal importance to all impacts. Our last parameter is the real discount rate used to convert future building product costs to their equivalent present value. Here, we accept the default rate of 4.2 %, the rate mandated by the U.S. Office of Management and Budget for most Federal projects (Office of Management and Budget, 1992; 2000).

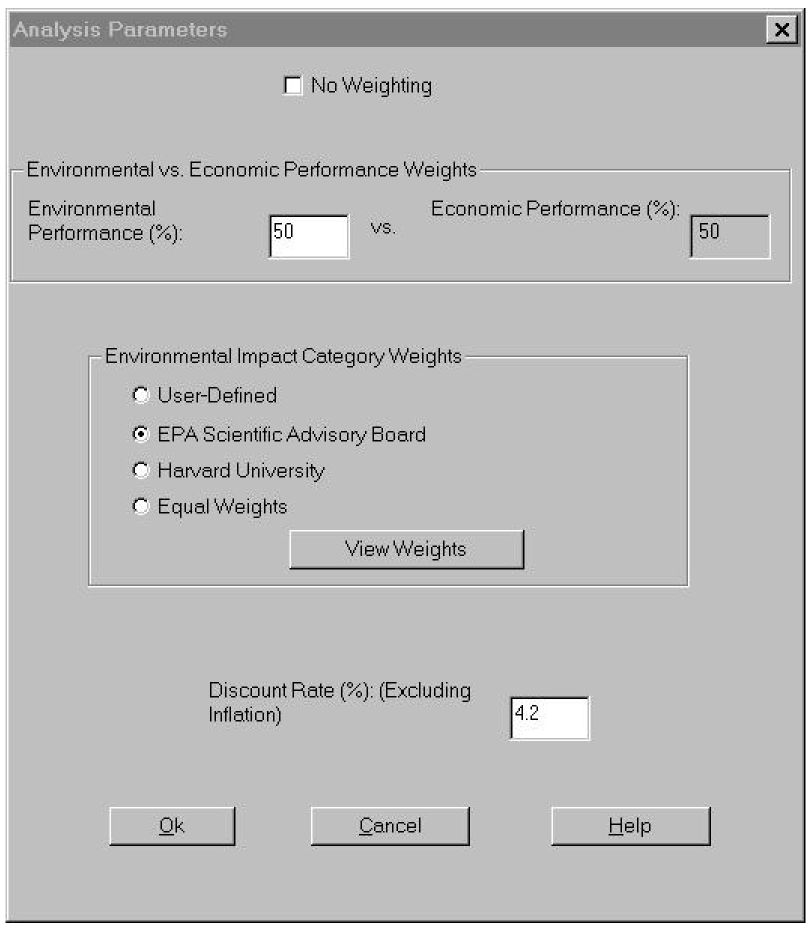


Figure 1. Setting BEES Analysis Parameters

Next, we need to set one last parameter for each of our exterior wall finish alternatives--the transportation distance from the manufacturing facility to the building in which the product will be installed. This parameter lets BEES compute an environmental performance score accounting for the significance of using locally-produced products. As illustrated in Figure 2, we have selected a transportation distance of 805 km (500 mi) for our vinyl siding alternative.

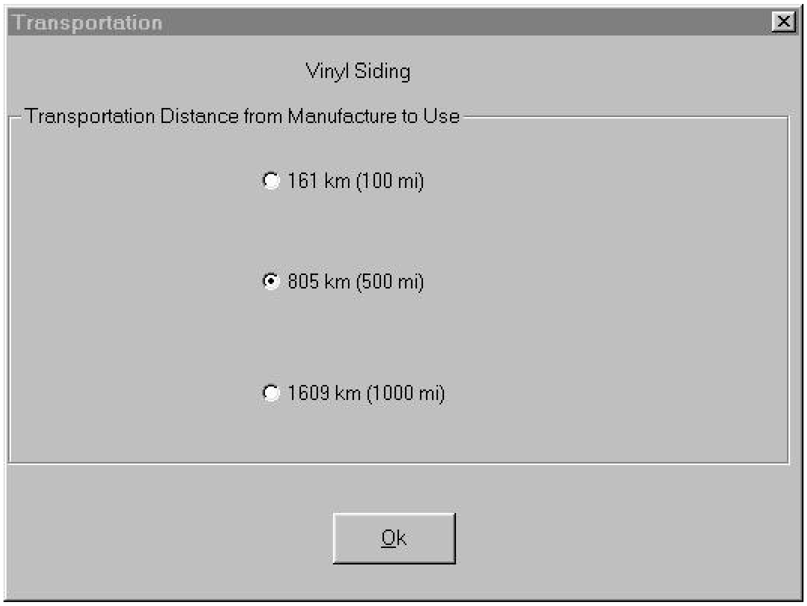
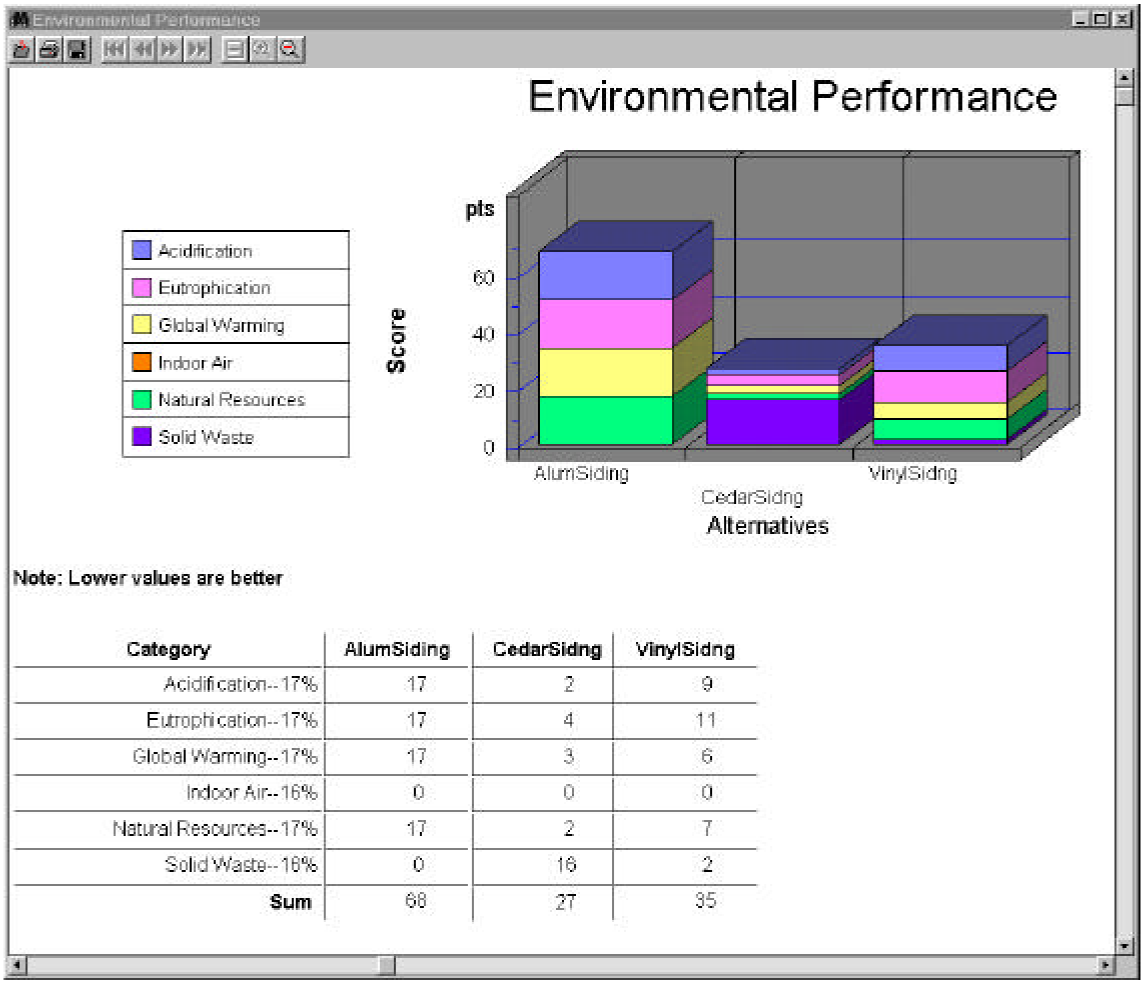


Figure 2. Setting Transportation Parameters

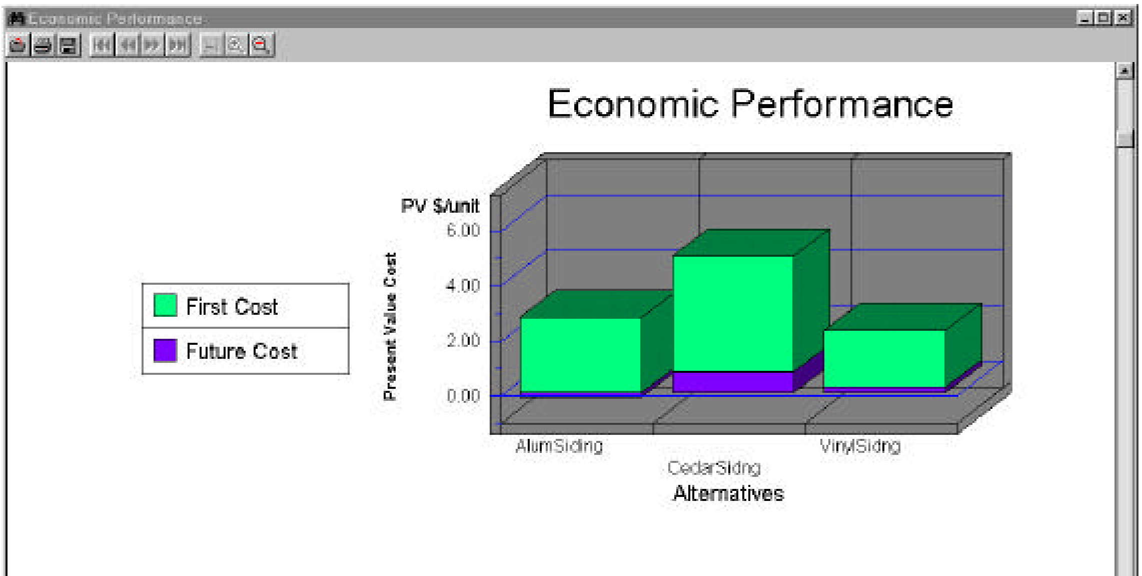
Now we are ready to compute and view BEES results. Figure 3 shows the BEES Environmental Performance Results displaying the weighted environmental performance scores for our example in both graphical and tabular form. Lower values are better; if a product performs worse with respect to all environmental impacts, it receives the worst possible score of 100 points. In our example, aluminum siding received a total score of 68 points, cedar siding a total score of 27 points, and vinyl siding a total score of 35 points. The figure breaks down the weighted environmental score by its six contributing, weighted scores for acidification, eutrophication, global warming, indoor air, natural resource depletion, and solid waste. As shown, cedar siding performs better on all impact categories except solid waste. Displayed on the table, next to each impact category, is its assigned relative importance weight.



Category	AlumSiding	CedarSidng	VinylSidng
Acidification--17%	17	2	9
Eutrophication--17%	17	4	11
Global Warming--17%	17	3	6
Indoor Air--16%	0	0	0
Natural Resources--17%	17	2	7
Solid Waste--16%	0	16	2
Sum	68	27	35

Figure 3. Viewing BEES Environmental Performance Results

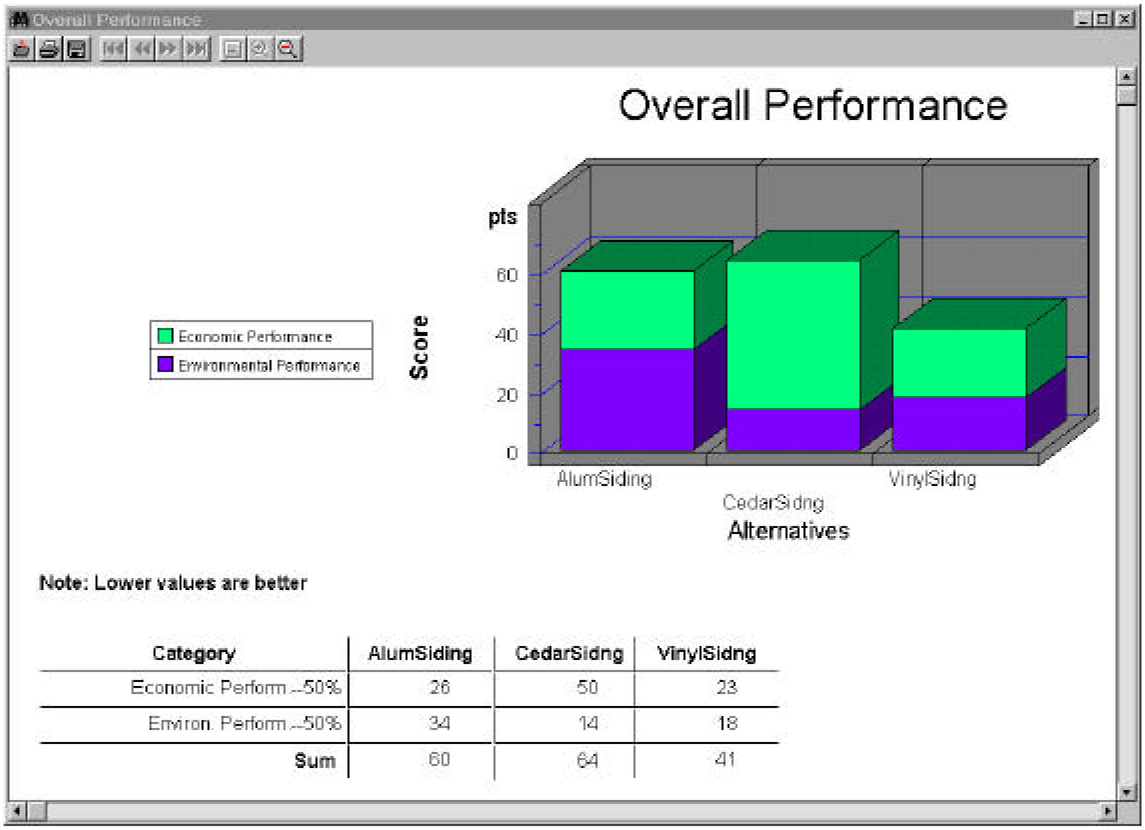
Figure 4 shows the BEES Economic Performance Results for our example, which gives first costs, discounted future costs, and their sum, the life-cycle cost. The figure shows that vinyl siding has the lowest life-cycle cost ($2.27 in present value dollars, compared with $2.60 for aluminum siding and $4.94 for cedar siding). Thus, based on our assigned discount rate of 4.2 % (displayed in the table next to the future cost category), cedar siding scores better environmentally, while vinyl siding scores better economically.



Category	AlumSiding	CedarSidng	VinylSidng
First Cost	2.73	4.17	2.07
Future Cost-- 4.2%	-0.13	0.77	0.20
Sum	2.60	4.94	2.27

Figure 4. Viewing BEES Economic Performance Results

The overall performance score gives us a way to combine and balance the environmental and economic performance scores. Figure 5 shows the BEES Overall Performance Results based on our equal weighting of environmental and economic performance. It displays the overall performance score for each product alternative, which is the sum of its weighted environmental and economic performance scores. Displayed in the table, next to each performance category, is its assigned relative importance weight. We can see from this figure that aluminum siding receives a score of 60 points, cedar siding a score of 64 points, and vinyl siding a score of 41 points. Thus, based on our analysis parameters, vinyl siding is preferable overall to aluminum siding and cedar siding. Note that besides the summary graphs shown here, BEES also offers detailed graphs for each environmental impact (e.g., reporting grams of carbon dioxide each product contributes to the global warming impact), which help pinpoint the "weak links" in a product's environmental life cycle.



Category	AlumSiding	CedarSidng	VinylSidng
Economic Perform.--50%	26	50	23
Environ. Perform.--50%	34	14	18
Sum	60	64	41

Figure 5. Viewing BEES Overall Performance Results

CONCLUSION

Applying the BEES approach to the scores of other products included in BEES 2.0 (including framing, exterior and interior wall finishes, wall and roof sheathing, ceiling and wall insulation, roof and floor coverings, slabs, basement walls, beams, columns, parking lot paving and driveways) leads to several general conclusions. First, environmental claims based on single impacts, such as reduced global warming 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, assessments 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 kilogram-for-kilogram basis, but if that product requires twice the mass as the other to cover one square meter 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 tradeoffs.

BEES will be expanded and refined over the next several years. First, many more products will be added to the system so that entire building components and systems can be compared. To that end, manufacturers are encouraged to submit brand-specific performance data through the new *BEES Please* program (contact: blippiatt@nist.gov). Second, more environmental impacts, such as habitat alteration, are under development for incorporation into future versions of BEES. Finally, U.S. region specificity and greater flexibility in product specifications (e.g., useful lives) are being incorporated. The intended result is a cost-effective reduction in building-related contributions to environmental problems.

ACKNOWLEDGEMENTS

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