NIST

United States Department of Commerce
Technology Administration
National Institute of Standards and Technology

NIST Special Publication 888

Second International Green Building Conference and Exposition–1995

A. H. Fanney, K. M. Whitter, and T. B. Cohn, Editors

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[1]At Boulder, CO 80303.
[2]Some elements at Boulder, CO 80303.

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August 1995

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National Institute of Standards and Technology
Special Publication 888
Natl. Inst. Stand. Technol.
Spec. Publ. 888
160 pages (Aug. 1995)
CODEN: NSPUE2

U.S. Government Printing Office
Washington: 1995

For sale by the Superintendent of Documents
U.S. Government Printing Office
Washington, DC 20402

PREFACE

This report constitutes the proceedings of the Green Building Conference held in Big Sky, Montana, August 13-15, 1995. The conference was sponsored by the U.S. Green Building Council (USGBC) and the National Institute of Standards and Technology (NIST), co-sponsored by the American Institute of Architects, American Society of Interior Designers, American Society of Landscape Architects, Construction Specifications Institute and Illuminating Engineering Society of North America and hosted by Montana State University.

The conference focused on the design, construction, operation, maintenance, and demolition of buildings in an environmental and cost-efficient manner. Sessions were held to specifically address the following topics and issues:

* Economic and environmental benefits of green building.
* Case histories of community scale sustainable development.
* Lessons learned from the Montana State University Green Building Project.
* An examination of land use issues related to green building development.
* Guidelines for specifying green products, evaluate environmental standards, and conduct life-cycle assessments.
* How to assemble a design team and the benefits derived from the team approach to green building design and construction.
* Specifications, bidding and negotiating contracts associated with green building construction.
* Operation and maintenance of environmentally efficient buildings.
* Adaptive re-use and proper techniques for environmental disassembly of existing buildings.
* Case histories of effective environmental design, construction, and operations programs for universities, office buildings, single-family residential, and municipal projects.
* Green building rating systems, product certification, new technologies, and future needs.

Keynote addresses were presented by Mac Bridger, Chief Executive Officer of Collins and Aikman Corporation and Ray Anderson, Chief Executive Officer, Interface, Inc.

This proceedings includes papers from the majority of the speakers. Nine of the 27 speakers failed to submit written text to the editors.

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GREENING THE BOTTOM LINE

Increasing Productivity through Energy-Efficient Design

William D. Browning
Rocky Mountain Institute
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Abstract

Energy-efficient building and office design offers the possibility of increasing worker productivity. By improving lighting, heating, and cooling workers can be made more comfortable and productive. An increase of one percent in productivity can provide savings to a company that exceed the entire energy bill. Efficient design practices are cost effective just from their energy savings. The resulting productivity gains make them indispensable.

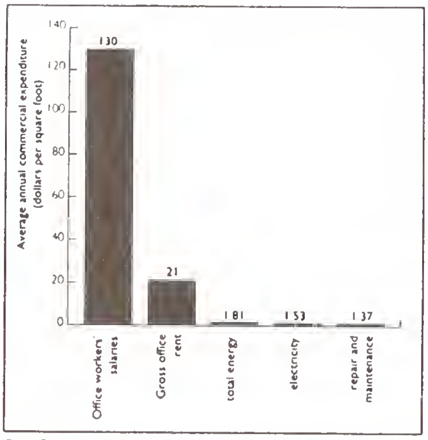
This paper contains exerpts from the study, *Greening the Building and the Bottom Line,* which documents several cases in which efficient lighting, heating, and cooling have measurably increased worker productivity, decreased absenteeism, and/or improved the quality of work performed. These cases show that productivity gains from energy-efficient design can be as high as 6% to 16%, providing savings far in excess of the energy savings. They also show that efficient lighting in particular can measurably increase work quality by reducing errors and manufacturing defects. This paper describes case studies of companies who undertook to increase the energy efficiency of buildings, and who thereby inadvertently increased worker productivity.

Introduction

"We shape our dwellings, and afterwards our dwellings shape our lives."
— WINSTON CHURCHILL

Energy efficiency retrofits for existing buildings, and new buildings designed for energy efficient performance have very attractive economic returns. For example, a three year payback, typical in lighting retrofits, is equal to an internal rate of return in excess of 30%. This type of return is well above the "hurdle rate" of most financial managers. The same retrofit may also cut energy use by 50¢ or more per square foot, which has significant positive effects on the Net Operating Income of a building. However, these gains are tiny compared to the cost of employees which is greater than the total energy and operating costs of a building.

Based on a national survey of the stock of offices for 1990[1], as summarized in the graph below, electricity typically costs ~$1.53 per square foot (85% of the total energy bill); repairs and maintenance typically add another ~$1.37 per square foot [2] ; both contribute to the gross office-space rent of $21 per square foot. Office workers cost ~$130 per square foot ~72 times as much as the energy costs. An increase of 1% in productivity is approximately equal to the entire annual energy cost.



Data from Building Owners and Managers Association. Electric Power Research Institute. Statistical Abstract of the United States 1991

Productivity is measured in production rate, quality of production, and changes in absenteeism. This can be improved by fewer distractions from eye strain or poor thermal comfort, and similar factors. It has been suggested that any change in a worker's environment will increase productivity.

Research done at Western Electric's Hawthorne plant in Chicago in the 1920s and 30s suggests that contrived experiments to monitor the effect of a workplace change on productivity can be complicated by the special conditions of the experiment, particularly the interaction between the worker and the researcher. Indeed, some have come to see the "Hawthorne effect" as implying that changes in the physical environment have an effect on worker performance only because those changes signal to the worker the interest and concern of management. Additionally, any gains are believed to be only temporary.

Subsequent analyses, however, have called into question the experimental methods and results from this work. The research pool included only five subjects, who, along with their supervisors, were being rewarded for gains in productivity, and could monitor their own production rate on an hourly basis. Despite these flawed tests, the Hawthorne research led to this widespread belief that changes in working conditions affect productivity only because they signal management concern. The effects of building design on productivity were basically ignored for 60 years, even though a major 1984 study of the effect of office design on productivity found direct correlation between specific changes in the physical environment and worker productivity.[3]

It is important to note that increases in worker productivity were not the reason for the measures described in this paper. The goal of the companies in these case studies was to create energy efficient workplaces. The gains in productivity observed by the companies were for the most part an unanticipated effect. Some of the companies were aware that the measures implemented would improve the quality of spaces.

The measures described herein were not energy conservation, but rather were measures to increase energy efficiency. Both activities lower energy consumption, however, conservation implies a decrease in service. Energy efficiency must meet or exceed the quality of service that it replaces. The decisions to undertake the energy efficiency actions were based solely on projected energy and maintenance savings. In all the examples the measures of productivity had always been monitored by the companies. Additionally, none of the cases involved a change in management style.

Retrofits

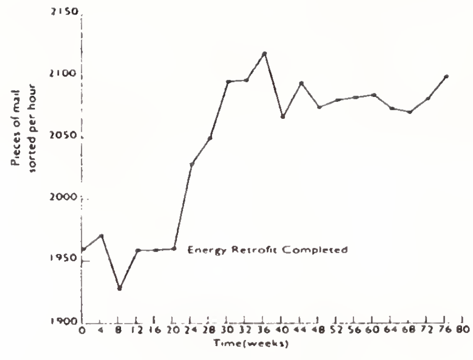
In 1986, the mail sorters at the Main Post Office in Reno, Nevada[4], became the most productive of all the sorters in the entire western region of the United States, which stretches from Colorado to Hawaii. At the same time, the operators of one of their two mechanized sorting machines achieved the lowest error rate for sorting in the western region. What happened?

It began a few years earlier when the Reno Post Office was selected by the federal government to receive a renovation that would make it a "minimum energy user." An architectural firm, Leo A. Daly, was hired to do everything necessary to reduce energy use.

The Post Office was a modern warehouse with high ceilings and coal black floors. It was quite noisy in the areas where the two sorting machines were run. The sorter is grueling to use. Once a second, it drops a letter in front of the operator, who must punch in the correct zip code before the next letter appears a second later. If the operator keys in a zip code that doesn't exist, or no zip code at all, the letter will immediately be sent through the machine for repunching. If the wrong zip code is keyed in, the letter will be sent to the wrong bin and it will take even longer to track down the mistake. The job is so stressful that an operator can work a maximum of 30 minutes on the machine at one time before being replaced by another operator.

The chief architect, Lee Windheim, proposed a lowered ceiling and improved lighting. The new ceiling would make the room easier to heat and cool, while also creating better acoustics. The ceiling would be sloped to enhance the indirect lighting, and to replace harsh direct downlighting. More efficient, longer lasting lamps that gave off a more pleasant light quality were installed.

Before starting the complete renovation, estimated to cost about $300,000, Windheim did a small section of the lighting and new ceiling. The idea was to leave it in place for a few months to see how it worked and if people liked it. The mock-up was done over only one of the two sorting machines. The graph below shows the number of pieces of mail sorted per hour in the 24 weeks before the change, and for more than a year after the change.



Productivity gain after retrofit

In the next 20 weeks, productivity increased more than 8%. The workers in the area with the old ceiling and lighting showed no change in productivity. A year later, as the graph below shows, productivity had stabilized at an increase of about 6%. A postal worker operating the machine was now sorting about 1060 pieces of mail in the time it used to take to sort 1000. Under the new lighting design, the rate of sorting errors by machine operators dropped to one-tenth of one percent (0.1%)—only one mistake in every 1000 letters—the lowest error rate in the entire western region. Working in a quieter and more comfortably lit work area, postal employees did their jobs better and faster. The manager of mail processing, Robert McLean says, "No one could poke holes in the story." The data were "solid enough to get $300,000 to do the whole building."

The energy savings projected for the whole building came to about $22,400 a year. There would be an additional savings of $30,000 a year from the new ceiling reducing the recurring maintenance cost of repainting the underside of the exposed roof structure. Combined, the energy and maintenance savings came to about $50,000 a year: a six-year payback. The productivity gains, however, were worth $400,000 to $500,000 a year. In other words, the productivity gains alone would pay for the entire renovation in less than a year. The annual savings in energy use and maintenance were a free bonus.

At the Reno Post Office, no one conducted any special experiment intended to raise productivity, and there was no unusual interaction between workers and supervisors. Productivity had always been measured. McLean, denies any personal responsibility for the improvement. McLean, now postmaster for Carson City, says, "We had the same people, the same supervisor, and I don't believe I was doing any motivational work." Yet he says that the data on the productivity and quality increase were solid: "It was irrefutable." The changes to the building were designed solely to reduce energy use. The increases in productivity were unexpected.

The Reno Post Office case had never been published, mainly because the managers did nothing to change how the employees were manged, and therefore felt that they could not take credit for the gain in productivity. This is an indication of the persistance of the Hawthorne mythology. After discussion, the managers were convinced that since it took a mangement decision to change the building, and therefore they could take credit for the gains in productivity.

The Reno Post Office wasn't even the most dramatic case. That honor arguably goes to Pennsylvania Power & Light[5], which in the early 1980s redesigned the lighting in a 12,775-square-foot building housing its drafting engineers. New fixtures were installed that directed lighting more specifically to work areas. That reduced the quantity of light required, and cut down on distracting glare and reflections off work surfaces.

The new lighting cost less than $8,500, and saved $2,035 a year—a 4.1-year simple payback, or a 24% annual return on investment. But that was just the start. Based on the time drafters took to complete drawings, the company calculated that productivity jumped by 13%—a gain worth $42,240 a year, bringing the total return on investment to 540%.

And there's more. The number of sick days taken declined by 25%. The number of drafting errors dropped, an improvement which the company estimates saved at least $50,000 a year. If the latter figure is included in the calculation, the return on investment soars to over 1,000%.

Other retrofit case studies include: Boeing's "Green Lights" effort that reduced its lighting electricity use by up to 90% with a 2-year payback, a 53% return on investment and reduced defects; and Hyde Tools implementation of a lighting retrofit with a one year payback and a $25k increase in product quality.

New Buildings

In 1978, Nederlandsche Middenstandsbank (NMB) needed a new image, and a new headquarters in Amsterdam.[6] According to Dr. Tie Liebe, head of Maatschappij voor Bedrijfsobjecten (MBO), NMB's development subsidiary, NMB wanted a building that was "... organic, which integrated art, natural materials, sunlight, plants, energy conservation, low noise, and water."

An integrated design team was instructed to work across disciplines — architects, construction engineers, landscape architects, energy experts, artists, and bank employees worked for three years on the design. The architect Anton Alberts describes the building, completed in 1987, as "anthroposophical," based on Rudolph Steiner's design philosophy. Rather than a monolithic tower, the 538,000 square feet (50,000 m^2) building is broken up into ten slanting towers. The irregular S-curve ground plan has gardens and courtyards interspersed over the top of 301,280 square feet (28,000 m^2) of parking and service areas. Restaurants and meeting rooms for the 2,400 employees line an internal street connecting the towers.

Like most northern European offices, the floor plates are narrow. Desks are located within 23 feet (7 meters) of a window for daylighting. Interior louvers in the top third of windows bounce daylight onto office ceilings. Atriums in the towers provide a significant portion of the lighting. Additional needs are met by task lighting, custom decorative wall sconces, and limited overhead fixtures. The building has double glazing, as it predates high-efficiency "superwindows." Insulation separates the brick skin from the precast-concrete structure which is used to store heat from simple passive solar measures and internal gains. Additional heat is supplied through hydronic radiators connected to a 26,420 gallon (100 m3) hot water storage system, heated by a cogeneration facility, and heat recovery from elevator motors and computer rooms. Air-to-air heat exchangers transfer the heat from exhaust air to intake air. The bank has no conventional compression chillers, it relies on the building's thermal storage, mechanical ventilation, natural ventilation through operable windows, and a backup absorption cooling system powered by the cogeneration system's waste heat. The integration between building design, daylighting and energy systems has yielded impressive results.

NMB's former headquarters consumed 422,801 BTU/square feet (4.8 GJ/m2) of primary energy, the new building consumes 35,246 BTU/square feet (0.4 GJ/m2) annually. In comparison, an adjacent bank, constructed at approximately the same time and cost, consumes five times the energy per square foot.[14] Construction costs of 3,000/m2 (ƒ1987) or $162 square feet ($1991) include; land, structure, landscaping, art, furniture and equipment. Costs attributed to the energy systems were approximately $700,000, however annual energy savings are estimated at $2.6 million.[15] Dr. Liebe said "construction costs were comparable or cheaper than other office buildings in Holland." Using early 1980s technologies the energy measures had a three month payback. NMB has "... the lowest energy costs in Dutch office buildings, and one of the lowest in Europe."

Sophisticated integration is evident from the artwork, plants and "flow form" sculptures. Expansion joints are treated as relief sculpture. Colored metal reflectors high in the atrium towers bathe lower spaces in colored light. Interiors feature a simple palette, texture paint over the precast concrete, wood trim, with wood slat and some drop ceilings. Cisterns capture rainwater for fountains and landscaping. Flow Form sculptures used extensively even in handrails, create a pulsing, gurgling stream of water that adds visual appeal, moisture to the air, and a pleasing level of white noise in the corridors.

Absenteeism among NMB employees has dropped and remained 15% lower than in their old building, Dr. Liebe attributes this to the better work environment of the new building. The building has done wonders for NMB's image, and "... NMB is now seen as a progressive, creative bank, and the bank's business has grown dramatically."

In some buildings, productivity gains were not expressed in terms of absenteeism or production rate. One such case is is a prototype Wal-Mart store opened in Lawrence, Kansas, in 1993.[7] The "Eco-Mart"—which RMI helped design—incorporated experimental features to make the store more energy-efficient and environmentally sustainable.

One of the main energy-saving features was an array of light-monitoring skylights to optimize the amount of daylight admitted into the store. To cut costs, Wal-Mart decided to install the skylights only in one half of the store. To their surprise, managers discovered that sales per square foot were significantly higher for those departments located in the daylit half of the store. What's more, employees in the artificially lit half began requesting that their departments be moved to the daylit side. Wal-Mart is now featuring the Eco-Mart concept in its advertising and is considering implementing many of the measures in its other stores.

Other case studies of new buildings include: Lockheed's engineering development and design facility that saved $500,000 a year on energy bills and gain 15% in production with a 15% drop in absenteeism; and West Bend Mutual Insurance's new building that has a 40% lower energy consumption than their previous facility, and uses individual workstation controls with a 16% increase in the claim processing.

Since the original study was published other cases have come to light. One example is in Costa Mesa, California. Verifone, the company that makes the key pad for telephone verification of credit cards, decided to turn a tilt-up concrete warehouse building into their world-wide distribution headquarters. The project was designed by Randy Croxton, of Croxton Collaborative which is best known for their work on the National Audubon Society Headquarters in Manhattan. Verifone has a strong environmental and social agenda, and wanted their new building to be energy efficient and a pleasant workplace. The building plan now includes an entry reception area leading to a rotunda, surrounded by meeting rooms. Adjacent to the rotunda is the main office spaces, with primarily open plan spaces and some enclosed rooms around the perimeter. Perpendicular to the center of the office space is a large open corridor that forms the spine of the building. On one side of the central portion of the spine is a components warehousing space, and on the other is the remanufacturing/product customization floor. At the far end of the spine is the main distribution warehouse. The modifications to the building included the addition of only three windows to the front facade, for a group of meeting rooms, and a series of skylighting schemes for the interior spaces. Daylighting was one the major strategies for energy savings in the facility, and the success of that strategy can best be seen in the remanufacturing area. In this space, the overhead lights are typically turned off on a sunny day, and the work on circuit boards is done with natural light and task lighting. The mechanical design included efficient air-handling and a gas-absorption chiller.

The Verifone facility was renovated in a very fast five month period. The design achieved a 50% energy savings and cost $39 per square foot. Verifone moved 168 employees from an adjacent building into the new facility. Absenteeism among those employees dropped from an average of 14.3 hours to 7.5 hours, and 45% decrease. Verifone now has a problem because employees remaining in the original facility are complaining that they want to be moved to the new building, so the company is undertaking a gradual retrofit of the older building.

Conclusion

The results of these case studies are impressive for two reasons: First, the measurements of productivity in most of the cases came from records that were already kept, not from a new study. Second, the gains in productivity were sustained and not just a temporary effect.

Of course, companies can improve their workers' output in all sorts of ways that have nothing to do with energy efficiency; and for that matter, they can increase energy efficiency in ways that don't necessarily improve labor productivity. But if a company is in the market to do one or the other, why not do both? Will just any energy retrofit produce gains in productivity? No, only those designs and actions that improved visual acuity, and thermal comfort seem to result in these gains. This speaks directly to the need for good design, a total quality approach that seeks to improve energy efficiency and improve the quality of workplaces. This is a point that seems to have been forgotten by many designers and building owners.

Clearly, there is a need for further research; however, the results of these few case studies indicate that the economic benefits of energy efficient design may be significantly greater than just the energy cost savings. That energy efficiency provides numerous benefits, has long been known. That it can lead to productivity gains far exceeding the energy savings gives it a new imperative.

Greening the Building and the Bottom Line: Increasing Productivity Through Energy-Efficient Design, can be ordered from Rocky Mountain Institute, 1739 Snowmass Creek Road, Snowmass CO 81654, 303/927-3851 / FAX 303/927-4178 Internet: orders@rmi.org

1 Building Owners and Managers Association (Washington DC), *Experience Exchange Report 1991*, at p. 95, showing national means for downtown 100–300,000-ft^2 private-sector office buildings in 1990. Areas are net rentable space; income ($21) is for the office area only, *vs.* $16.68 for the entire building including retail space, parking, etc. The energy costs, other costs, and income, are probably somewhat higher for new offices than for the stock average described here, which is based on a sample of hundreds of buildings totaling >70 million ft^2. The authors are grateful to BOMA for kindly making these proprietary data available.

2 The *Statistical Abstract of the United States 1991*, Table 678, p. 415, gives 1989 average office salaries whose weighted average was $27,939/yr. We nominally adjust this by 4.12% for 1989–90 monetary inflation (implicit GNP real price deflator) and add an estimated 20% for taxes and benefits, then divide by the BOMA 1990 national average of 268 ft^2/officeworker in 100,000–300,000-ft^2 office buildings.

3 For a survey of some of the literature on the flaws in the Hawthorne effect research—and a major study that came to a different conclusion—see Michael Brill et al, using *Office Design to Increase Productivity, Volume I*, (Buffalo; Workplace Design and Productivity, Inc., 1984), pp. 224-25. See also William J. Dickson and F. J. Roethlisberger, *Counseling an Organization: A Sequel to the Hawthorne Researches* (Boston: Harvard University Press, 1986). This book explains that the traditional view of the Hawthorne Effect -- the workplace environments affects productivity only because it signals management's interest in the worker -- is very different from what the Hawthorne researchers themselves concluded from their work. They concluded that productivity can be enhanced by a more cooperative relationship between management and labor, and a greater identification by workers with the goals of management, and more effort by management to treat workers with respect and to be responsive to their needs and abilities.

4 The Reno Post Office case was developed from personal communications with Lee Windheim of Leo J Daly, and Robert McLean of the US Postal Service.

5 This case is based on Russell Allen, "Pennsylvania Power and Light: A Lighting Case Study," *Buildings*, March 1982, pp. 49–56; "Office lighting retrofit will pay back in 69 days," *Facilities Design & Management*, p. 13.

6 This case comes from William Browning "NMB Bank Headquarters, The Impressive Performance of a Green Building," *Urban Land*, June 1992 pp. 23-25, and William Browning "NMB. Bank" *Progressive Architecture*, May 1993, and personal communication with Dr. Tie Liebe, and Anton Alberts.

7 This case study is based on our design consulting for and analysis of the EcoMart, and personal communication with Tom Seay, Wal-Mart's Vice President for Real Estate.

8 This case study is based on personal communications with Randy Croxton of Croxton Collaborative, and on-site interviews of Verifone facility staff and management.

DEMYSTIFYING GREEN BUILDINGS

David Gottfried
Gottfried Technology, Inc.

An environmentally designed and operated structure requires an integrated team approach, from project inception through completion. The risk of not working together in this way is an inefficient and more costly building. For a green building to work, input and coordination are required from the building's architect, interior designer, site planner, engineers, building owner and manager, building occupants, product manufacturers, and local utility.

The goal is to design, construct, and operate aesthetic buildings that meet all of the occupants' needs while performing at optimum efficiency. The ultimate cost does not have to be more, rather the design should be more efficient. Green buildings have three main components: energy efficiency, resource efficiency, and worker health.

Energy efficiency. Constructing an energy-efficient building requires optimization of the shell, daylight penetration, and mechanical and electrical systems, including plug loads.

Solar performance should be optimized. The proper glazing (and shading) systems should be carefully selected for the building and its respective sun exposures. The albedo of building roofs is receiving a lot of attention. Light color roofs are much more reflective and absorb less heat than dark roofs, which can result in lower internal cooling requirements.

The building systems should be sized to the users' end needs. Mechanical systems typically can be downsized if the building shell, lighting systems, and plug loads are efficient. Mechanical efficiency can be achieved through proper sizing and control of the system. Environmentally designed buildings have been shown to consume as little as 20 percent of the energy required in other code-compliant buildings.

Many new mechanical and plumbing systems offer energy-efficient opportunities that can be properly controlled according to the occupant's use. Energy-efficient motors, variable speed drives, control valves, efficient cooling towers, boilers, fans, occupancy and VOC sensors, heat recovery systems, peak demand storage and thermal systems, heat pump systems, and other such advanced mechanisms all lower energy consumption. HVAC system should comply with the Montreal Protocol's required phase-out of CFC-based refrigerants. Plumbing systems should minimize both the energy consumption in producing hot water and water in general.

Lighting systems should be based on specific tenant requirements as indicated in the furniture layout. Task and ambient lighting strategies should include occupancy and photo cell controls. The individual loads at the electrical outlets also should be evaluated.

Resource efficiency. Many natural resources used in building materials are becoming scarce. Aesthetic and cost effective building materials are now being made from recycled-content products, including tile, drywall, under-layment, MDF board, and carpet.

In the United States, there are now some demonstration houses built predominantly of recycled materials. Some products made with a high level of recycled content are actually cheaper than products made from virgin material.

Life-cycle analysis is emerging as the science for evaluating the efficiency of a given product. ASTM's Green Building Subcommittee E-50.06 is drafting life cycle standards for the building industry that look at the entire process of producing and using a product, from materials extraction through reuse or disposal.

Worker health. Areas where employees' health and productivity are concerned include indoor air quality (IAQ), lighting quality, thermal comfort, and noise pollution. Among these items, IAQ has received the greatest attention. Achieving good IAQ depends on the building materials and ventilation system. Increasingly, design professionals are requesting not only Material Safety Data Sheets on particular products, but also the results of any chamber test "off-gassing" studies.

Aside from a product's off-gassing properties, one should also attempt to evaluate its relative toxicity. Many products contain preservatives and other chemicals to prevent bacterial growth and extend product life. Manufacturers are now reviewing their expanded products' menu of environmental components and re-engineering them accordingly.

Smoking is still the worst indoor air pollutant. The Environmental Protection Agency (EPA), the Building Owner's Management Association, ASTM's Green Building Subcommittee, and the U.S. Green Building Council all recommend that smoking be excluded from buildings.

Once a green building has been created, the green ethics process looks at the operation and management of the building and its occupants. At the end of the building's useful life, it should take on a new life, which could include its reuse for another function, or its disassembly and the recycling of its parts (building blocks) for reuse in another application or product creation. This evolution is now known as the "life cycle" of the building - a "cradle to cradle" process. The concept of "cradle to grave" is no longer acceptable; society can no longer afford the financial and waste reality of the "grave". Landfill tipping fees will increase significantly within the next decade, and construction and demolition debris may no longer be accepted at traditional landfills, but will be required to be separated and reused accordingly.

Environmental Materials Matrix

Specifiers can evaluate a product using an environmental product matrix (see Figure A). Each category is assigned a relative importance rating (which should vary depending on the project and relative team priorities), by which materials can be selected. Traditional architectural selection criteria also should be added to the matrix.

To date, there is no national database for such information; however, entities such as CSI and the U.S. Green Building Council are starting to address the need for such critical information.

Figure A. Materials matrix categories

Environmental Categories

- Off-gassing = VOC level (particles per billion)
- Percent recycled content
- Product end of life recyclability
- Product relative toxicity level and elements
- Product embodied energy
- Product packaging related waste
- Life cycle calculation
- Manufacturer product recycling program review
- Manufacturer environmental reputation and track record

Traditional Selection Categories

- Price
- Availability
- Ease of use
- Performance, durability, and life of product
- Aesthetic considerations
- Code and standards compliance
- Manufacturer warranty and reputation

National Green Building Activities

The pace of national green building activity has greatly accelerated over the years.

Many green building standard activities are coming out of ASTM's Green Building Subcommittee E-50.06, which is working on standards for commercial and residential buildings. The standards provide general guidance on how to design a green building; perform a life cycle (improvement, impact, and valuation) assessment for building products and materials; and assess sustainably harvested wood and environmentally preferable cleaners and degreasers. Many other standard-setting societies such as ASHRAE, IES, and ISO also are working on green building-related standards.

Many local, state, and federal agencies as well as the model building codes are looking at ways of incorporating environmental parameters such as energy and resource efficiency, waste, and indoor environmental quality into their regulations and programs.

Gottfried Technology, on behalf of the U.S. Green Building Council, is writing a book for Public Technology, Inc. (PTI) and the U.S. Department of Energy (DOE), called *Green Buildings Demystified.* PTI is the non-profit research, development, and commercialization arm of the National League of Cities, the National Association of Counties, and the International City/County Management Association. Its members include hundreds of local governments falling under these categories.

The DOE is pursuing sustainable building programs through its Office of Building Technology, including the Federal Energy Management Program and Rebuild America Program. The office is also considering new heating and cooling systems, lighting and windows research, codes, and standards. DOE's laboratories are also doing green work.

Lawrence Berkeley Laboratory is developing energy-efficient software and electrochromatic windows and performing indoor air quality research. Battelle Pacific Northwest Laboratory is performing a building benefits analysis and launching a CAD-related energy software package.

The EPA just announced its Green University Program, which entails a partnership with George Washington University. Its goal is to provide for a sustainable future at the university in five principal areas: administration, education, research activities; health care services; and facilities, grounds, and infrastructure. Additional EPA programs include Green Lights, Energy Star Buildings, and Energy Star Computers.

The White House has been a leader in the green building field through its *Greening of the White House* project, which includes the Old Executive Office Building. In authorizing this national example, President Clinton stated, "For as long as I live and work in the White House, I want Americans to see it not only as a symbol of clean government, but also a clean environment. We're going to make the White House a model for efficiency and waste reduction." The project entailed assembling a team of approximately 100 experts from across the country who made recommendations in 12 environmental building categories.

The White House has sponsored other environmental initiatives, principally through its Office of Science and Technology.

The cabinet-level Subcommittee on Construction and Building for the National Science and Technology Council has been active in setting global environmental priorities for the building industry. Its lead groups include representatives from the Department of Commerce, DOE, and the National Science Foundation. In total, 11 agencies are participating in the effort.

A recent Request for Proposal for a U.S. Embassy to be built in Germany stated that the embassy should be an environmental showcase for "(a) energy efficiency; (b) the use of resource-efficient materials, indoor air quality, minimization of construction wastes, and efficient use of existing infrastructure; and (c) compatibility of office technology with human psychological and physiological needs."

The National Institute of Standards and Technology's Building Environment Division has an extensive group of environmental programs, including waste minimization; energy conservation; air, soil, and water quality; indoor air quality; ozone depletion and global warming; and green building design.

The national leader within the local government green building scene is the City of Austin. Its Green Builder Program includes many initiatives, from guidelines for residential design and construction to regulated guidelines for all work performed on city buildings. Many other U.S. cities are following Austin's lead.

Many demonstration green buildings are emerging throughout the United States. The most highly publicized has been the renovation of the National Audubon Society's building in New York. Other green building projects include the renovation of a building for the City of San Diego in partnership with the Electric Power Research Institute and San Diego Gas and electric; Souther California Gas Company's innovative Energy Resource Center; PG&E's Act projects; the California State Polytechnic University Center for Regenerative Studies; the Verifone corporate facility; Herman Miller Corp.'s new Phoenix Furniture line manufacturing facility; and the Gap and Patagonia's retail store and corporate facility projects.

Successful completion and written evaluation of these new projects will provide the design and construction industry with much needed feedback on material selection, systems performance in the field versus "as modeled," ease of installation and durability, and economic information on first cost, life cycle costs, and employee productivity increases.

Product Certification and Rating Systems

Several U.S. entities have emerged that specialize in product certification for the building industry. Green Seal and Scientific Certification Systems, the two main organizations, create standards for building products based on their own guidelines. Both entities include varying degrees of public comment, although neither follows a consensus process that is as complete and rigid as that followed by ASTM. Once a standard has been developed, the organizations review manufacturer product information. If the product information and associated specifications and performance data exceed the standard, then the product receives the organization's certification and associated seal.

The power and potential impact of product certification is enormous. It will heavily influence product specification and purchase. Of utmost concern to the public and especially to specifies should be the underlying basis and assumptions for the standards and associated "stamp of approval." Building owners and tenants rely upon specifiers to review the important environmental issues and specify accordingly.

In addition to rating and certifying building materials, certain entities such as the U.S. Green Building Council are proposing to rate structures for their respective environmental efficiency and performance. Such programs have already been implemented in the United Kingdom and Canada. In the United Kingdom, tenants are now considering the environmental performance rating of a structure in addition to its quoted rent and location. The building's overall value and lender's credit risk will ultimately be influenced by its environmental performance rating.

Green Building Economics

The National Science and Technology Council Subcommittee on Construction and Building's Preliminary Report points out that construction is one of the nation's largest industries. In 1993, new construction activity amounted to $470 billion (8 percent of the GDP) and employed 6 million persons. When renovation is included, construction amounts to approximately $800 billion annually (13 percent of the GDP) and employs 10 million people. The report further states that more than 50 percent of the nation's fixed reproducible wealth is invested in constructed facilities. Despite all of this, the Civil Engineering Research Foundation noted in a 1993 study that construction-related R & D is only 0.5 percent of construction value.

Given the magnitude of these figures, the green building precepts of energy and environmental efficiency and performance can have an overwhelming impact. Energy efficiency alone can yield operating savings in excess of 50 percent on an annual basis. Productivity increases can amount to savings of up to 15 times the annual energy bill (see Joseph Romm's *Lean and Clean Management*). This area entails the most significant economic potential for the rationale of green buildings. All owners and especially owners/occupants need to closely review the results of completed case studies and accordingly change the manner in which they carry out design and construction projects. Other economic savings can result in water, waste reduction, product costs, and accelerated construction schedules.

In addition to annual savings as a result of green building design, new financial products are emerging within the industry. One of these is the idea of "leasing" a product, as opposed to its outright purchase. Interface Corp., a leading innovative carpet manufacturer, has recently implemented the nation's first environmental carpet lease program, Called an "Evergreen Lease." It provides for the installation, on-going maintenance, replacement, and environmental reuse of leased carpeting. The lease has no term to it, theoretically lasting as long as the subject building is standing. Interface is responsible for the recycling and reuse of the carpet after it has been removed the facility.

Another financial concept being developed is the leasing of the building's mechanical heating and cooling systems, by selling "comfort" instead of the actual systems. The mechanical company provides the system and the cool water in the build at its own expense, and then charges a monthly fee for conditioned air. The tenant and building owner do not have to worry about the specification, maintenance, or replacement of the HVAC system.

Conclusion

Over the ensuing years, we will see the building industry incorporate the precepts of green buildings. Though the focus is on energy and environmental efficiency and occupant health, the overriding base is economic savings. The result does not have to cost more, rather the entire design, construction, and operational processes are orchestrated by different parameters, answering to the highest level of performance criteria.

Author's Note

The U. S. Green Building Council is the nation's only non-profit coalition of the building industry advocating the advancement of environmental building standards education, demonstration, and analysis CSI is an active member of the Council. This article originally appeared in The Construction Specifier, June 1995.

DEWEES PHILOSOPHY

John L. Knott, Jr.

As the issues of growth increasingly confront the issues of environment, we must ask the question, "Is man a functional part of the natural system or an interloper that has no place on this earth?" This question may sound absurd, but take a few moments to consider the controversies you have either experienced or read about over the last decade.

The philosophy of Dewees is that we **are** an **essential** participant in the environment. We simply need to re-discover our intuitive base as to how to live in harmony with our environment as well as re-learn how to select habitat and nest within it (as opposed to dominating and destroying more than we need). The history of great architecture and historic communities throughout the world is a history of designing and building in the context of natural elements and geography. With that in mind, the question arises, "What changed our ability to plan, design,and construct communities and buildings that functioned so well and felt so good?"

As the industrial revolution evolved and our technological prowess emerged, three major forces altered our thinking. The first was a sense of control and power that allowed us to do anything we wanted. Electric power, air conditioning, elevators gave us a sense that we could build anything, anywhere, anyhow because we could control what was inside. The second was telecommunications, which eliminated the need for proximity to afford effective communication. The third was our automobile passion, which has shifted our focus from planning for people to planning for cars... which also had the net effect of destroying public transportation systems, isolating communities and de-personalizing our lives. Add to these factors, a sense that all resources were unlimited and you have the recipe for our current crisis; a crisis where people and the environment have become enemies.

The underlying principles of Dewees are that:

. Development and environment are natural allies
. All development & building should occur in the context that all resources are limited
. Communities and buildings can be resource providers not just resource users
. Land is a stewardship role for future generations
. It is less expensive short and long term to build in harmony with the environment
. Communities are planned for people and technologies are to be **supportive** not dominant
. Environmental education is an essential "first step" in the re-discovery of our intuitive sense of integrating with the environment

Dewees Philosophy

In order to integrate these principles into a development and/or building program, you need to build a data base on the natural site resources of topography, geology, vegetation, sun, wind and water.

All built environments have four areas of cost considerations after land acquisition and zoning approvals.

. Infrastructure required for finished sites
. Infrastructure repair and replacement
. Construction of building and site finishing
. Operating and replacement costs of buildings

Developing and building in the context of natural resources, using buildings as resource providers, building with the premise that all resources are limited, and choosing materials compatible with environment will reduce most of the above costs and produce a more marketable product as well as reduce demand on municipal tax dollars.

The costs that govern land development are grading, roads, storm drain, water quality, and landscaping. The driving forces that control these costs are public works regulations, storm water volume and land development regulations. If we reduce paving, we reduce all other costs. If we reduce storm water run-off, we reduce storm drain and regional pond costs. If we control siting of homes by the discipline of natural systems, we will reduce their operating costs as well as long term maintenance and repair. If we build energy efficient and resource providing homes built with regionally available and environmentally compatible materials, we will improve short and long term performance and achieve higher quality.

A SUSTAINABLE DEVELOPER'S PERSPECTIVE ON ENERGY

JOHN L. KNOTT, JR., CHIEF EXECUTIVE OFFICER/MANAGING DIRECTOR

DEWEES ISLAND, SOUTH CAROLINA

In nature, energy is converted from one form to another. Waste is not a factor since the by-product of one species is another species' energy source. Ecosystem models reflect connectedness and interdependence of all biologic functions at the individual level working as a system. As we today make our human habitat decisions, could we make the same statement regarding how our communities work or how we design and implement decisions for energy, habitat creation, water, waste, transportation, communication and atmosphere?

It is my belief that we must return to some basic principles, which were present prior to the industrial revolution. Prior to this period, we could not create habitat and ignore geology or climate if we were to survive. We could not distribute our population across wide areas of land because they could not transport efficiently for work, play, resources, gathering or worship. They could not communicate except by letter or face to face. In short, we could not waste or expend resources as we do today.

Adopting a resource efficiency strategy as opposed to only an energy efficiency strategy is the vehicle to achieving an economic, social, and environmentally sustainable community. This approach considers the resources of energy, people, time, capital, land, natural resources, water, wind and air as connected and interdependent, when forming individual and community habitat decisions. A resource efficient approach generates reduction in capital infrastructure, repair and replacement costs, as well as operating costs leaving our limited resources available to more members of our community, increasing individual and community resources for education and social needs, and decreasing violence which is directly related to resource deficiency. Secondly, resource reduction dramatically increases the economic viability of alternative technology applications. Thirdly, we move to a more distributed vs. centralized and a matrixed vs. linear system for energy,

REFERENCES TO REALITY

ABSTRACT

IN 1991, Dewees Island's owners and a group of investors formed Island Preservation Partnership and pledged to create a "private, oceanfront island retreat dedicated to environmental preservation." To get started, the group enlisted John Knott, a third-generation builder specializing in preservation and conservation to "create a community where people can live with the environment without having negative impacts."

Mr. Knott's mission is to create a sustainable community on the 1,206 acre island, more that 350 acres of which is a wildlife preserve. Development plans for the island affect less than 10 percent of the site Sustainable features on the Dewees Island include:

- Residents can have only electric-powered vehicles:
- All roads and driveways are made of pervious material, like crushed limestone, shells, or sand. Paving isn't allowed because it hinders runoff absorption and would pollute the island's terrain and aquifer restoration.
- Houses must respect the traditional forms of South Carolina, lowcountry designs, with eaves, porches, and operable shutters.
- Although lot sizes average more than two acres, no more than 7,500 square feet can be disturbed.
- Tree locations must be considered in locating building site. Preservation is required, and relocation, if necessary.
- Formal lawns are not allowed. Landscaping must be native to Dewees or the South Carolina Coastal Plain.
- Sixty-five percent of the island is forever protected from development.

In his presentation, Mr. Knott will speak about his philosophy of sustainability and how that philosophy fits in with his job as a land developer. Mr. Knott will also speak on the infrastructure of sustainable community development and why it makes economic sense.

DESIGNING SUSTAINABLE SYSTEMS

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Abstract. Sustainability is an overarching principle for all development. To support the hydrologic cycle, ecosystem stability and other critical natural processes, it is necessary to consider global and regional issues on developments of all sizes. In contrast to a sustainable approach, the modern infrastructure and conventional planning methodologies represent a cultural indifference to the uniqueness of each place, to the understanding of environmental systems and to the amount of energy it requires to maintain this infrastructure. This is especially true with respect to the dynamics of water flow and plant ecology. Site planning and environmental planning as a whole must integrate natural systems into problem solving techniques, using indigenous materials and basing design on historical patterns of terrain, water and climatic disturbance.

Introduction

Over the past 150 years of civilization, we have become a society that is largely unaware of the reality of our surroundings, disconnected from the functioning of natural systems, and unmindful of the importance of the human relationship with the natural environment. "Civilized" people seem distant, no longer attentive, no longer accountable, and often oblivious to the way the world works.

We have become comfortable living in a machine world, surrounded by inanimate objects and a "rationalized" natural system, a system that becomes more convoluted and volatile the more it is constrained. Cities are increasingly plagued by poor air quality and are barely able to provide damage control as their infrastructure ages. Persistent flooding on the Mississippi is the signature of an accelerated runoff pattern that begins in uplands and only grows to recognizable proportions downstream, after it has become a problem with catastrophic consequences. The loss of biodiversity is synonymous with the tragic loss of one high profile endangered species after another, but what is even more tragic is that these losses are indicative of the decline of entire habitats. In all of these cases, the standard policy has been to treat the symptoms and ignore the root causes of the ailment. Smog alerts do not remove particles from the air, migration to the suburbs will not revitalize an urban center, FEMA will not stop flooding, and legislating the protection of one species will not necessarily stabilize the ecosystem upon which it depends. The basic premise of sustainability is a demand that we bring the development of each and every place into line with our goals for the regional and global environment.

The misconception that human enterprise can be separated from the natural world has proven a serious roadblock to sustainability. When applied to the land, the polarization of "human" and "nature" often results in the notion that sustainability equates to simply "letting nature take its course." This misguided belief threatens our ability to stabilize, manage, and restore the world's remaining natural areas, and hinders attempts to create naturalized systems where we have already lost them.

The degree of human alteration of the physical environment during the past 150 years across America has transformed the evolution of this landscape from a process driven by a balance of climate, hydrology, ecology, and the niche adaptation of Native American peoples to a process largely driven by and dependent upon the consumption patterns and aesthetics of modern humans. In the modern American land use scheme, climate is a cursory consideration, and hydrology and ecology are the patchwork products of utilitarian planning. Given the set of conditions present in the global environmental system today, it is growing more and more likely that a truly self-sustaining ecosystem is not feasible - humans are, in essence, maintaining an ecosystem of their own design, with an incomplete relationship to dynamic physical processes. To the planners of the environment, sustainability rests on two interrelated goals: first, working towards the renewal of self-replicating, sustainable systems; second, minimizing the amount of energy required to indefinitely maintain the plants, streets, buildings, and other artifacts of human design that we place on the landscape. In contrast to our current land ethic, environmental decision-making must slowly and deliberately examine our impacts to the global and local environment, balancing the needs of today with the requirements of millions of years of evolution yet to take place.

Detached from natural processes and unaware of their capacities, it is easy to understand how a culture could adopt a land ethic that challenges the frontiers of every continent and the thresholds of every natural law. Not only does our culture rely on technology for dealing with environmental problems, but also for food production, transportation, health, communication, and many other basic needs. It is only one more small step to believe that technology is all we need, that technology already has or ultimately will satisfy every conceivable question or exigency. In order to produce the technology that supports both our basic needs and our quest for "progress," the modern economy relies on divesting the earth of its natural resources.

In A Sand County Almanac, Aldo Leopold wrote "we abuse land because we regard it as a commodity belonging to us. When we see land as a community to which we belong, we may begin to use it with love and respect." (1) Designers, planners, developers, and engineers should look upon the natural world as a model and as a technology itself. Just as medicines are isolated from plants and insects, so too are many of the solutions to sustainable living waiting to be found in the technology of nature. Bioremediation to treat effluent and spoils; greenways to provide transportation alternatives and connected corridors of habitat; and plant community restoration to reduce runoff and erosion, and to create less maintenance intensive landscapes; these are but a few examples of natural systems being used within a cultural context.

Throughout the post-glacial period, and perhaps for 100,000 years or more, human beings have been making conscious choices about their relationships to the land. Human cultures have matured and evolved in synchronicity with the natural environment, including both flora and fauna.

In a short span of a very long planetary history, the human species has effectively inhabited every type of environment on the globe. However, this fact should not be taken to imply that humans will be able to maintain a certain quality of life. If the human species is to prosper, it must assume the role of steward. A burgeoning population to shelter and feed makes sustainability, as an overarching principle for all development, not just a good idea, but an ecological and economic imperative. On a local level, many natural systems need to be considered. To uphold water quality, water must be managed in a comprehensive manner, taking into account natural peak flows in streams and rivers, and also the intricate plant matrix that promotes natural seepage and groundwater recharge. Soils, and the plant and animal habitats that reside upon them, should be productive and stable. Urban growth must foster public awareness of the environment and integrate site development within the patterns of the natural systems upon which it is superimposed. These are the missing links, the institutions and innovations of a culture that will be able to pass the legacy of the Earth to each successive generation with outright certainty that the legacy has only just begun.

Working With Natural Systems

Conventional site planning and development, from corporate and institutional campuses to residential subdivisions, epitomizes the loss of connection between humans and the larger community to which we belong. Home and working environments are often characterized by vast tracts of closely mowed turf grass, accompanied by regimented beds of ornamental shrubs, flowers and ground covers, and a variety of introduced and largely non-native trees. While this seems innocuous enough, the generic landscape produced in this conventional mode is static, and functional from the standpoint of visual considerations only. While planting designs could be a starting point for sites that would *evolve* into a cohesive relationship with the sites and systems around them, all intention typically stops at the boundaries of the property and at the starting point in time.

The view that landscape architecture is somehow a derivative of architecture has become ingrained in the thinking of those who purchase and even those that provide the bulk of these services. The buildings and the landscape look very similar throughout a city, a region, the country. So rarely is "place" taken into account that more often the landscape looks like an extension of the buildings around it than buildings look like an extension of the landscape which surrounds them. Nearly every developed site in the American landscape is treated with the same relatively small palette of plants, placed in deference to the gestures of formal design, in groupings of 5's and 7's. Executing a site plan is similar to the closing day between a building contractor and a new tenant: when a site plan is purchased, it is typical to demand that the desired appearance of a landscape be attained as immediately as possible, and then expect it to be maintained indefinitely. This requires, for example, the installation and perpetual replacement of large, costly trees, most of the time relegated to rooting environments where it is certain that they will be short-lived.

Contemporary developed areas are composed of few other living things. Those plants found in urban areas are from either the narrow palette of "landscape" plants, or they are the select weeds that are adapted to highly disturbed or compacted areas. While "landscape" plants are strategically located, and at least perceived to be important, these plants usually have no relevance except for the fact that they achieve visual and basic functional goals. They are the plants that have proven easy to propagate, are duly compact and geometric in form, and are tolerant of salt and soil compaction. The animals that reside in urban environments are also signatures of an ecosystem that is neither self-sustaining nor self-replicating. Rodents, pigeons, and droves of lost geese are the most successful foragers in an environment where the food supply is limited to landscape plants, garbage, and the occasional gift from human well-wishers. One thing can be said for the urban ecosystem: its distinguishing characteristic is its lack of biodiversity.

Does the modern infrastructure prescribe that the outdoors look and feel like the indoors, or is this a choice we are making? In terms of the appearance of buildings and the placement of plants, it is definitely a choice, albeit one with tremendous social inertia. In terms of other choices, hydrology, for example, the complexity of the problem has driven a process where mechanical solutions are built to counter the problems of other mechanical solutions for other problems. In this case, natural systems can be used to redesign the infrastructure itself, to improve not only the visual quality of these systems, but the efficiency with which they operate.

In the Chicago area, approximately 37 inches of precipitation fall annually, equaling about one million gallons of water for each acre of land. Most turf grass lawns possess shallow root systems, incapable of infiltrating even minor rainfall events. Pore spaces become quickly saturated, resulting in an environment that is extremely efficient at shedding its water. Water is non-compressible and flows downhill. This flow generates energy that transports topsoil, fertilizers, pesticides, and other materials, turning them into pollutants. Buildings, roadways, parking lots, and water bodies generate pure runoff. Runoff generated from roadways and parking areas often contains a variety of harmful constituents.

Water is a precious resource, held in a tenuous hydrologic balance between evaporation and precipitation. In the Chicago area, one million gallons of water fall on each acre per year, and about one million gallons of water are naturally evaporated from each acre per year. Due to urban, suburban, and agricultural development, much of the one million gallons that falls on each acre is largely sent off-site. Since one million gallons is still evaporated on each acre per year, our water budget is in deficit.

By in large, water is handled as a waste product, to be safely and efficiently conveyed from the site as quickly as the law will allow. Depending upon local ordinance, this can range from almost immediately, to 0.05 cfs/acre - a slow, steady dribble. Since water must leave a site quickly, but not too quickly, it requires an intricate and costly storm sewer network, coupled with the construction of an appropriate complement of detention and retention basins. What is referred to as a retention or detention basin, however, is often nothing more than a hole in the ground. These types of basins have one function: to delay the release of the water until it can be metered into area streams, lakes, or rivers, in accordance with the locally allowable release rate. These functional holes in the ground are not productive "ponds", "lakes", or "wetlands". They do not support a diverse population of aquatic vegetation or wildlife. In fact, they rarely perform another basic function, which is to attenuate pollutants. In the hydrology of storm sewers and detention ponds, fertilizers, sediments, and pesticides are metered out into our streams and rivers in lock step with all runoff and without discrimination.

Storm sewers and detention ponds are only part of the problem. Cool season turf grasses, mostly Eurasian such as Kentucky Bluegrass, possess shallow root systems incapable of penetrating clay tills. Since they can hold little water, the turf dries out within hours of the last rain. The solution is to install expensive irrigation systems to mine water deep from within the ground. The shallow root system also renders these grasses incapable of competing with other, more aggressive weeds, particularly when roots become stressed, drying out during the summer heat. Constant mowing is required to prevent other plants from ecologically out-competing the turf grasses, and also to maintain the neat, trimmed rug appearance. In order to maintain the desired green, weed free, homogenous appearance, we water, fertilize, and apply pesticides. Of course the next time it rains, these resources head for the detention basins, and eventually nearby streams. For every gallon of fossil fuel burned in the maintenance of traditional landscapes, about 15 pounds of carbon dioxide are released into our atmosphere. This carbon dioxide has not been a part of the earth's ecosystem since the Paleozoic era.

The site that results from this combination of pressures is so inherently unstable that few organisms can reside long enough to establish long-term, resource cycling systems. Instead of systems rich in a community of organisms, composed of a connected and interconnected diversity of living things, our environments are largely composed of steel, tar, concrete, vast blankets of monoculture, and a few weeds. Such environments are products of a contrived visual aesthetic with little or no understanding, relationship, or grounding in the unique realties of place.

The notion of belonging to a place is a profound concept. In the manifestation of an ideology that separates the human from nature, we do not view ourselves as an active "part of" the natural process, we have become separated, and quite "apart from" the natural process.

We appear comfortable living in a culture that is unsustainable by design. What is most striking, however, is that we are typically *un*comfortable with the idea of sustainability, primarily because it involves change. At the site level, it seems to make very little difference whether the chosen approach is one of natural swales, carpooling, and solar heating; or that of storm pipes, single rider commuting, and conventional utilities. Whether one is contributing to the problem or contributing to the solution, the contribution is deemed so small to begin with that the overriding factor in development is not the energy wasted or conserved within each site design, but the amount of energy it will take to sell and politically implement alternative concepts. In this situation, conventional planning and development often appears to be the most conservative option: why expend extra energy to contest local and federal regulations, find special building materials, or enlist design services which don't conform to the status quo?

In terms of the status quo, what we find is that the modern landscape requires intensive maintenance on an extreme scale. One commonality of almost all conventional landscapes is the high level of maintenance required to preserve its desired appearance. Conventional approaches in landscape development generally require frequent lawn watering, mowing, pruning, weeding, trimming, and the liberal application of chemical fertilizers and pesticides. This perpetual cycle of care is executed in the name of maintaining a desired visual aesthetic that is repeated over and over with little relationship to site or regional environmental functions. Why spend extra energy up front to shift away from the status quo? If for no other reason, to defray the long term costs of maintenance.

Defining the Problem of Sustainability

It was earlier concluded that the contemporary urban environment has neither the plants nor animals of a self-replicating ecosystem, but the question remains: given human initiative, can this ecosystem be *maintained* indefinitely? The weight of this question is especially heavy given the rate at which this urban ecosystem is growing. In 1940, one of every 100 people lived in a city of population 1 million or more. In 1980, one in ten people globally lived in cities of one million or more. Within the foreseeable future, over half the world's population may live in large cities, and of the remainder, quite a few will live in cities smaller in population, but no less urban in their effect on the ecosystem.

As land continues to be converted to urban uses, it becomes increasingly clear that the costs of supporting a deficient ecosystem are far greater than the costs of changing the standards of development. We lose agricultural land and habitat to urbanization. In the remaining agricultural areas, we lose topsoil to erosion. Each inch of topsoil loss results in a six percent reduction compared to previous yields on every acre of land. Meanwhile, our population grows. In the equation of current trends, we put in more energy to attain the same yield, to feed more people. The mechanics of unsustainability may seem esoteric, but they effect us on a profound scale.

Given human initiative, we can choose to live sustainably, or we can choose to divert more and more resources into maintaining a poorly integrated ecosystem. If we choose the latter, we can expect, at best, to get in return only what we contribute in the first place. In the latter case, however, it is more likely that the inevitable strains on various components of the system will cause the entire ecosystem to set into a downward spiral.

That we are facing a decision of staggering significance to our future is only beginning to be understood. It is encouraging, however, that this understanding comes from sources as divergent as scientific data and spiritual writing, to environmental lobbies and the tides of consumer demand. Such a cusp has made sustainability more tangible, and the growing vocabulary for sustainable planning is necessary both to hone in on effective problem solving techniques and to inspire widespread interest in the issue.

Awareness

Most of us know that the water flows into the nearby storm inlet. We are not sure where it goes from there. It is, however, out of "site." During major storm events our rivers exhibit massive surges of filthy water. Sometimes we get flooded. Sometimes, areas downstream from us get flooded. We are not sure why, but we believe that creating bigger holes to detain more water will relieve the flooding. Carried out on an enormous scale, this seems to help, so we continue building in flood prone areas. The fact remains, however, that the cumulative effect of numerous detention basins, in certain situations, can be as harmful as if no safeguard had existed in the first place. If our current methods of dealing with different aspects of the hydrological cycle are emblematic of our appreciation for its significance, we have a poor understanding indeed of this very essential component of life on Earth.

Education

There is no one factor more critical to the concept of sustainability than education. In the words of David W. Orr from his recent article, *Educating for the Environment*, we are a society that "must be educated into existence".(2) We believe that most humans, given the choice, would prefer to conduct their lives in a way that would insure a quality living experience for their children and generations of grandchildren to follow. First, however, the public must believe that a problem really does exist, that the standard approaches are not sustainable, and that economically and environmentally sensible alternatives are available. The basic constraint is that most people are simply unaware of the impacts associated with conventional development. Until corrected, lack of public awareness continues to erode the best laid plans of architects, landscape architects, planners, developers, and all others who have a stake in shaping the environment. Environmentally responsible planning will not be a reality until the demand for such planning grows and the suppliers of these services are willing to take the lead in informing a cultural awareness for environmental decision-making. Orr suggests that "One of the principal tasks of education in the coming century is to foster ecological design intelligence, which requires a careful meshing of human purposes with the larger patterns of the natural world." (3)

What has made modern civilization such a destructive endeavor? What obstacles have prevented us from harmoniously "meshing" human purposes with their environmental setting? The primary obstacle facing sustainable planning and design is that no one profession has the depth of training and skills necessary to implement it alone. Sustainability requires a multi-disciplinary approach. Traditional academic degrees and professional training generally lead us to believe we have earned the competence to solve very specific types of problems. When asked what their degree will allow them to do, or what their job involves, who will answer "sustainable design" when sustainable design is beyond the purview of any one degree program or career track? Is sustainable design made illegitimate by virtue of the highly regimented academic and professional system in which it must survive?

As Orr points out, "The ideal of a broadly informed, renaissance mind has given way to the far smaller idea of the academic specialist." (4) In James Alexander Thom's Panther in the Sky, the author relates an account of a conversation between the great Shawnee leader Tecumseh and his friend Galloway, who informed Tecumseh about an expedition of scientists from Harvard traveling to Iowa in the summer of 1806 to observe an eclipse. Tecumseh curiously asked his friend to explain what a scientist does. Galloway described a scientist as someone who "studies the things of earth and heaven...Scientists watch plants and animals, they watch stars, they watch clouds and rain, and the earth..." "Do not all white men do this?" Tecumseh asked. "All Shawnee do this." (5)

By reassessing traditional educational principles, it will be possible to combine an enormous base of scientific knowledge with an appreciation for the problems and experiences that can only be realized collectively. The breadth of the sustainable problem is ultimately an advantage, because the hope for tomorrow is so locally relevant that it simply cannot remain the territory of professionals alone, all society must be involved. Decision makers at every level must be educated, from local, state and federal governmental representatives to the individual inhabitants of each community. Already land planners are advocating "democratic" design, community meetings as part of the design process, and other variations on this theme. The fabric of nature and culture is so complex, planning professionals are discovering that sustainable design approaches may only be achieved by drawing upon, and learning from a broad spectrum of expertise. In this capacity, the challenge to planning and design professionals is to synthesize these ideas creatively. This is a model for education, that future professionals - and all citizens for that matter - are accountable for knowing how to learn something new when it is relevant, and for being an active participant in the process of inventing the future.

A basic role of education should be to teach us how to learn, to prepare us for a lifetime journey of learning. Jock Ingels, President of LaFayette Home Nursery in northwest Illinois, has been advocating the integration of natural plant communities and a sustainable approach to planning for more than 25 years. Rather than refer to himself as an expert, he prefers to describe himself as an "explorer." Educators would do well to train a generation of explorers. The seeds of a sustainable curriculum for these explorers are already planted in academic departments that encompass a wide breadth of social and physical science, that teach problem solving as both an aesthetic and technical synthesis. The leaders of future sustainable development must be able to facilitate a dialog between environmental scientists, engineers, builders, planners, architects, and a public that expects quality of life to be supported by its environment. Landscape architects, inherently interdisciplinary in their training, are primed to inform a critical new connection between practitioners of these different disciplines.

An increased understanding and awareness of the relationship of human activities and natural systems will provoke a fundamental shift in aesthetics and engineering. A new aesthetic will emerge based on *both* visual and environmental functions. Conversely, infrastructure will not only be functional in a utilitarian sense, but visually engaging and environmentally sensitive. Systems that work within the unique patterns of place will be perceived as attractive. As people's awareness of sustainable realities expand, the attributes of environmentally grounded design will be simply and clearly communicated, without any hindrance to formal and purely aesthetic design goals.

Public perception and market demand may change rapidly once the problem of sustainable living is better understood and practical solutions are illustrated. As Paul Hawken suggests in The Ecology of Commerce, "shifts in culture can occur in rare moments with remarkable speed and vigor." (6)

The Role of Design and Development Professionals

"If it comes down to a decision between good design and the environment, I'll always opt for good design." Thus proclaimed a design practitioner in one of the professional design journals. This is a curious statement. How do the criteria for "good design" differ from those for "the environment?" Does "good design" not subsume a good environment? Many architects and landscape architects view environmental considerations as a constraint to their artistic freedom. Is it possible, however, to achieve good design without incorporating an understanding of the dynamic relationship a project has to both the built and natural environment? Sustainable design is *more* than artwork, *more* than a painting or a piece of sculpture, it is the achievement of artistic goals within the parameters set by the chain of an unfolding past and future. The design of environments where humans and other organisms interact, where actions create reactions, where future is built upon the past, requires an appreciation that good design and the environment are positively synonymous. From buildings, sites, and cities, to the world as a whole, the design of sustainable environments means facilitating human purposes in concert with other dynamic processes.

If we are to successfully shift toward sustainability, we must first address several basic shortcomings that are pervasive throughout the planning and design professions. Design professionals must learn to recognize the drawbacks associated with continued reliance on the standard default, an unwieldy combination of visual aesthetics and functional design. Another reality that must be clearly understood is that every site is unique unto itself. The real challenge to planning and design professionals becomes the development of aesthetically pleasing, innovative design solutions that creatively integrate environmental considerations, along with other relevant development factors, into the design process. Such designs must still incorporate critical visual interest, but also integrate physical and behavioral patterns.

Once we understand the realities of place, that true freedom is possible only within these limits, there are infinite opportunities for design expression. Since every place is unique, every design will require new creativity, innovation, and technology. A new aesthetic, encompassing every aspect of infrastructure, will emerge in accordance with how successful we are at designing whole systems. This requires a design process based on the interconnection of dynamic systems, from the individual site through to the regional level.

Standard design and development approaches generally involve an attempt to mitigate impacts after the project is completed. Instead of having to mitigate impacts after the fact, their causes should be anticipated during design, thus turning potential impacts into site development assets. The building and site must be viewed as one continuous system, with tremendous potential to influence, either positively or negatively, the success of the whole.

An understanding of the unique physical characteristics of the site is critical, including, but not limited to, soils, flora, fauna, geology, aspect, and drainage patterns. In our opinion, if sustainability is to be achieved, water management, including both surface and ground water hydrology, is the key. There is no other resource or form of energy beyond light, with the ability to sustain or destroy, more powerful than water. Structural problems, soil erosion, flooding, degraded water quality and aquatic systems, and the loss of plant and animal species diversity can all be directly related to the mismanagement of water. Most planners and engineers address the need to understand pre-development hydrology. We recommend the need to comprehend pre-settlement hydrology. The earth's natural systems did not evolve with the type of surface water hydrology, both in terms of quantity and quality, to which they have become regularly subjected. The successful restoration of remaining natural areas, those remnants of the earth's living tissue, will require that we first address the form of hydrology under which they evolved and can be sustained.

The primary goal of both the building and site should be, wherever possible, to retain the water where it falls, treating the water as a resource, not discharging it as a waste product. This will require new design innovations throughout the built environment in the form of buildings that detain water, redesigned drainage systems, and the integration of plant systems, with specific water holding capabilities, that are uniquely adapted to the region.

The integration of plant systems adapted to the specific locale is an important component of the sustainable process. At an ecosystem level, there is little to no scientific evidence that any flora besides that native to a given region has the capability, through genetic memory and competitive hierarchy, to coalesce itself into self-replicating systems. This fact is of profound importance. This is not to suggest that the use of traditional ornamental plant species be abolished, but, rather, that a balance between the use of indigenous and non-indigenous material should be considered. This balance is determined by the site itself, in association with existing and proposed land use functions. From a design standpoint, the tremendous variety of native species found throughout most regions provides a limitless array of design opportunities. Whole micro-climates may be designed to respond to soils, hydrology, orientation, and the relationship to the building and other natural systems.

A primary goal of sustainability is the design of environments that enhance one's ability to comprehend, that encourage exploration and involvement, and are supportive of human needs and actions. Sustainable environments will communicate an understanding of environmental patterns and processes and engage human interaction. Orr contends, "when human artifacts and systems are well designed, they are in harmony with the ecological patterns in which they are embedded. When poorly designed, they undermine those larger patterns, creating pollution, higher costs, and social stress." (7)

Management is another critical component of the sustainable process. Typically, design professionals remain actively involved through the completion of project construction. Afterwards, the designer rarely returns to the site to evaluate its performance. Sustainable design, regardless of whether its building or site, requires a more active follow-up role. From the site perspective, the integration of naturalized plant communities in more traditional development settings and the incorporation of innovative water management measures, necessitates follow-up in the form of curation, or on-going site stewardship.

The need for an on-going relationship with each project highlights another important point. Sustainability is based, in part, on our understanding of the natural environment, coupled with the uniqueness of each design application. Because sustainable design is still in its formative stages, and our scientific knowledge is incomplete, there is no insurance that our initial applications will be highly successful. If we examine our current landscape, however, we must conclude that many "innovations" in housing, agriculture, transportation, and industry have generated little in the way of positive returns on the enormous investments we have made in them. A case can be made to support an approach that is only partially successful, versus one that is highly unsuccessful. Early attempts to create sustainable design will not always end up achieving the goal of indefinite sustainability, which only highlights the need to index what works, and provide for continued refinement.

Some consider advocating the integration of native plant species and naturalized plant communities as an attempt to reverse the biological evolution of an emerging modern landscape. Yet the support for a design philosophy using indigenous plants is far from mere romanticism. Scientifically, a commonly accepted ecological tenet is that plants and animals grow in habitats to which they are adapted. A corollary is that if the habitat is changed, so also will the inhabitants change. Within the timeframe of natural evolution, 150 years is little more than a blink of the eye. Plant species, through millennia, have become adapted to the specific combinations of biotic and abiotic factors, processes, and floral and faunal interactions uniquely characterizing the site they inhabit. An area with a long history of biome-level stability, such as characterized most of the presettlement landscape in the North America, will almost always support a diverse assemblage of locally prevalent species in self-replicating, interactive arrays. The diversity and complexity facilitate system adaptability to the gradual but inexorable changes that occur in all landscapes on a scale of thousands of years. Environmental factors may change over time, but they are gradual and sufficiently buffered by system complexity to allow the system to adapt at a rate commensurate with the life cycles and the genetic dynamics of the populations of its component biota. The result is that each variance of topography, physiography, geographic position, and substrate is characterized by an essentially unique response and inhabitancy by plants and animals.

Impacts to native biological systems and processes associated with European settlement, however, have occurred with a magnitude and rapidity without precedent in the history of the continent's biota. There is a striking difference between areas inhabited by a full component of locally prevalent plants and animals and one inhabited predominantly by weeds. The so-called "conservative" systems, with locally prevalent species, contain a biodiversity which suits that system to inhabit an area with long-term stability. Weed communities, by comparison, are adapted either to catastrophic disturbance or the kinds of activities associated with traditional cultural landscapes. These weed communities contain neither the biodiversity nor the aggregate adaptive ability to coalesce into self-replicating, sustainable systems. In our contemporary, fragmented landscapes, the conservative elements of our native systems, supplanted in place, have neither refuge, effective migration routes, nor the time to adapt or relocate. Rather, their populations are decimated time and time again until their local extirpation or ultimate extinction occurs. The destiny of many systems dominated by weeds is further destabilization, during which resources such as soil, nutrients, and water are often lost at rates faster than they are replaced. To cite an example, the average topsoil depth across the state of Iowa at the time of settlement was estimated at 18 inches. In 1990, the average topsoil depth was estimated to have been reduced to 8 inches. These are rich, organic soils of the prairie, formed over thousands of years of dynamic interaction with the flora and fauna of the region, through the annual process of carbon fixation, organic matter decomposition, oxidation and reduction. Once these soils are lost, no amount of fertilizer or technology will replace their viability.

Establishing a sustainable relationship with the living earth requires the reintroduction of a capacity for change. The real world is alive in the sense that each acre is inhabited by a community of species interlinked in time, space, and genetics, with the vital adaptive memory of *genius loci*. It is alive in the sense that each new year the community supplies the stability necessary for each species, relying on the great strength and adaptive success of their last generation, to persist long enough to experiment with new combinations of genes the earth has never seen, to respond to an earth that is never exactly as it was the year before. Ironically, without this long term, community-enforced stability, evolutionary change for most plants and animals cannot occur. To do this, we must first preserve and nurture those few remaining natural areas, the refuges for the living tissue of the earth. These are the places where the wisdoms of sustained existence are housed.

Economics

Sustainable development is inherently cost-effective, not only in terms of reducing environmental costs, but also with respect to the reduction of initial capital development and long term maintenance costs. The integration of buildings and landscapes that hold water, coupled with stormwater management systems that rely on naturalized surface drainage systems, can result in a significant overall reduction of site infrastructure. The use of plants that do not require supplemental irrigation systems, also serves to reduce initial construction costs. Our experience indicates that annual maintenance costs associated with native plant systems can be as little as 10% or less than comparable maintenance of traditional landscapes.

While new development may offer the most design flexibility for integrating sustainable measures, retrofitting existing buildings and sites will likely have a more immediate, positive impact, both in terms of cost savings and environmental benefits.

Summary

Building a sustainable relationship with the living earth requires that our actions be grounded in environmental realities. In a culture driven society, this requires an ethic. Since the beginning of the Holocene, and perhaps for much of the Quaternary, an important component involved in the shaping of the landscape has been humankind. Human beings are not only governed by stochastic or random interactions within the ecosystem, but by choice. Fundamental interactions such as predation, competition, and foraging are further complicated by the fact that humans can decide how to act, with no ecological parameter coming to bear on this decision other than a human ethic. According to Leopold, "All ethics so far evolved rest upon a single premise: that the individual is a member of a community of individual parts. His instincts prompt him to compete for his place in the community, but his ethics prompt him also to cooperate. The land ethic simply enlarges the boundaries of the community to include soils, waters, plants and animals, or collectively: the land. We can be ethical only in relation to something we can see, feel, understand, love and otherwise have faith in. A land ethic, then reflects the existence of an ecological conscience, and this in turn reflects a conviction of individual responsibility for the health of the land." (8)

Currently, we define progress, economic health, and prosperity by per anum growth rates, the standard of living, and other indices that do little to forecast or ensure the security of tomorrow.

What if we learned to define progress by the extent to which we reinvested in the natural resources of the Earth, and stewarded the land that it might work with us in that pursuit? Imagine the jobs, prosperity, and capital formed, as we redesigned and rebuilt agricultural, corporate, residential and industrial North America intelligently, attentive to sustainable realities and keeping an eye toward tomorrow. Humans would again become connected to the land, connected to something solid, something incorrupt, where memories of yesterday foreshadow the glories of tomorrow.

Too often, the response of people who are acquainted with a new idea or an unlikely vision is to dismiss it. "That will never work", or "Nobody would ever do that", or "Current ordinances won't allow that." Think back to 1830. In Chicago, prior to the steel plow, the prairies around Chicago and west into Iowa were too tough to till, and in many instances, too wet anyway. A young farmer, standing at Fort Dearborn and looking west across the vast land, could not have imagined, in his wildest fantasies, that it would be farmed from there to the Rocky Mountains in his lifetime. There was no market for it, no government to administer it, and no community base to support it. Yet it occurred, and it was achieved by one farmer, one at a time and in the aggregate, seeking to accommodate the economic imperatives of their day.

Currently, we have only a glimpse of such a tomorrow. If we are to create lands and ultimately regions, woven together by interconnected, sustainable systems, it cannot be done all at once. Rather, it will be implemented in increments, by a diversity of people, in a diversity of places, learning from small mistakes, and making small progresses.

Hawken suggests that "It is precisely in the discipline imposed by the limitations of nature that we discover and imagine our lives. It is only in the fullest context of the world as it is presented to us, and not as we manipulate it, that we may celebrate our humanity and create true prosperity. Such perspectives can lead us to a very different type of economy and way of doing business, one that will be healthier for all species, not only the butterfly and owl, but our own." (9)

Given acclamation to a sustainable ethic, the only Achilles heel, with respect to our tomorrow, is the continued loss of our natural areas. These areas contain the capital, principal, the endowment upon which tomorrow's sustained economy depends, the living fabric of the earth that we must graft back into our land. There is wisdom for those that believe in an ancient metaphor: the creator, in defining the human being, established a covenant between the human and the very earth itself. The creator mandated that the human being has dominion over the birds of the air, the fishes of the sea, and the beasts of the land. It is an awesome responsibility, subject to the casual, sometimes self-destructive tendencies of humans, because if that covenant is real, then the corollary is true: The extent to which we impoverish the air of the birds, the sea of the fishes, and the land of the beasts, is the extent to which we forsake our humanity.

The world has its realities, yet its possibilities are infinite if we stay within the rules. Let us learn and flourish in them. If we apply ourselves to those realities, set out the specifications to accommodate them, only few of which we know how to achieve at the moment, whole new technologies, industries, agricultures, and societies will develop, each needing its practitioners. Let us set the specifications for tomorrow, driven by an underlying ethic of sustainability. This ethic makes the idea of waste obsolete, replacing it with a view that all things are a resource. This ethic dispels the conundrum of growth, the division of "human" and "natural." Sustainable growth renews this important but imperiled symbiosis, opening the avenue to an infinite tomorrow.

Pilots must know the limits of their aircraft. They are immediately accountable for understanding the laws of flight, having an intuitive but thorough knowledge of aerodynamics, weather, and the controls of an airplane. If they are inattentive, or simply unaware of these laws, they may die. If they fail to observe the limits of their aircraft, it does not matter if they are a caring, well-meaning person. On the other hand, if the pilot is attentive to the limits of the vessel in which they fly, infinite freedoms are available. As the nucleus of a movement to create a sustainable planet, let us strive to understand this vessel and guide it to a place where our culture will weave itself into a wellspring of life.

HIGH FLIGHT

Oh, I have slipped the surly bonds of Earth
    And danced the skies on laughter-silvered wings.
Sunward I've climbed and joined the tumbling mirth
    Of sun-split clouds, and done a hundred things
You have not dreamed of. Wheeled and soared and swung,
    Hung in the sunlit silence hov'ring there, I've chased
The shouting wind along and flung my
    Eager craft through footless halls of air.
Up, up, the long delirious, burning blue I've topped the
    Windswept heights with easy grace,
Where never lark nor even eagle flew.
    And while with silent lifting mind I've trod
The high untresspassed sanctity of space, put out
    my hand and touched the face of God.

by John Gillespie Magee, Jr.

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SELECTING ENVIRONMENTALLY AND ECONOMICALLY BALANCED BUILDING MATERIALS

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Abstract. The building community wants to move toward the use of building materials with improved environmental performance at little or no increase in cost. A methodology for evaluating the environmental and economic performance of building materials is described. This methodology is being implemented in decision support software that will access a publicly available database of environmental and economic performance data for building materials. The software will assist designers and manufacturers in comparing the environmental/economic performance of alternative building materials. The National Institute of Standards and Technology is collaborating with the U.S. Environmental Protection Agency in this effort.

Introduction

Buildings significantly alter the environment. According to Worldwatch Institute [1], building construction consumes 40 percent of the raw stone, gravel, and sand used globally each year, and 25 percent of the virgin wood. Buildings also account for 40 percent of the energy, and 16 percent of the water used annually worldwide. In the United States, about as much construction and demolition waste is produced as municipal garbage. Finally, unhealthy indoor air is found in 30 percent of new and renovated buildings worldwide.

Negative environmental impacts flow from these activities. For example, raw materials extraction can lead to resource depletion and biological diversity losses. Building materials manufacture and transport consumes energy, which generates emissions linked to global warming and acid rain. Landfill problems, such as leaching of heavy metals, may arise from waste generation. All these activities can lead to air and water pollution. Unhealthy indoor air may cause increased morbidity and mortality.

Selecting environmentally preferable building materials is one way to improve a building's environmental performance. To be practical, however, environmental performance must be balanced against economic performance. Even the most environmentally conscious building designer or building materials manufacturer will ultimately want to weigh environmental benefits against economic costs. They want to identify building materials that improve environmental performance with little or no increase in cost.

The National Institute of Standards and Technology (NIST) is teamed with the U.S. Environmental Protection Agency's (EPA) National Risk Management Research Laboratory, Air Pollution Prevention Control Division, to develop by 1997 a standardized methodology and publicly available database for balancing the environmental and economic performance of building materials. EPA is developing a database of environmental performance data, and, with EPA support, NIST is developing the methodology and implementing it in decision support software for building designers and materials manufacturers. NIST is adding economic performance data to the database. The decision support software will access the database of environmental and economic performance data. The combined software and database product will be known as BEES (Building for Environmental and Economic Sustainability).

Measuring Environmental Performance

Environmental performance is measured using an evolving, multidisciplinary tool known as life-cycle assessment (LCA). LCA is a "cradle-to-grave," systems approach for understanding the environmental consequences of technology choices. The concept is based on the belief that all stages in the life of a material generate environmental impacts and must therefore be analyzed, including raw materials extraction and processing, intermediate materials manufacture, material manufacture, installation, operation and maintenance, and ultimately recycling and 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 general LCA methodology is as follows. LCA begins with goal identification and scoping (defining boundaries). What is the purpose of the LCA? What decision is the LCA meant to support? Where are environmental impact boundaries to be drawn--secondary environmental impacts, tertiary impacts? Do we include all environmental impacts, or only a predefined subset of impacts?

After goal identification and scoping, the four-step LCA analytic procedure begins. The *inventory analysis* step identifies and quantifies the environmental inputs and outputs associated with a material over its entire life-cycle. Environmental inputs include water, energy, land, and other resources; outputs include releases to air, land, and water.

The *impact assessment* step characterizes these inputs and outputs in relation to a comprehensive set of environmental impacts. For example, the impact assessment step might relate carbon dioxide emissions to global warming.

The third step, *impact valuation*, synthesizes the environmental impacts by combining them with stakeholder values. For example, assume there are only two environmental impacts, stratospheric ozone depletion and global warming. The impact valuation step might combine quantitative measures of ozone depletion and global warming into a single measure of overall environmental impact by normalizing the quantitative measures and weighting each impact by its relative importance. (Note that while LCA practitioners generally agree on the nature of impact valuation, not all treat it as a separate LCA step. Some include it as part of impact assessment, while others include it as part of improvement assessment.)

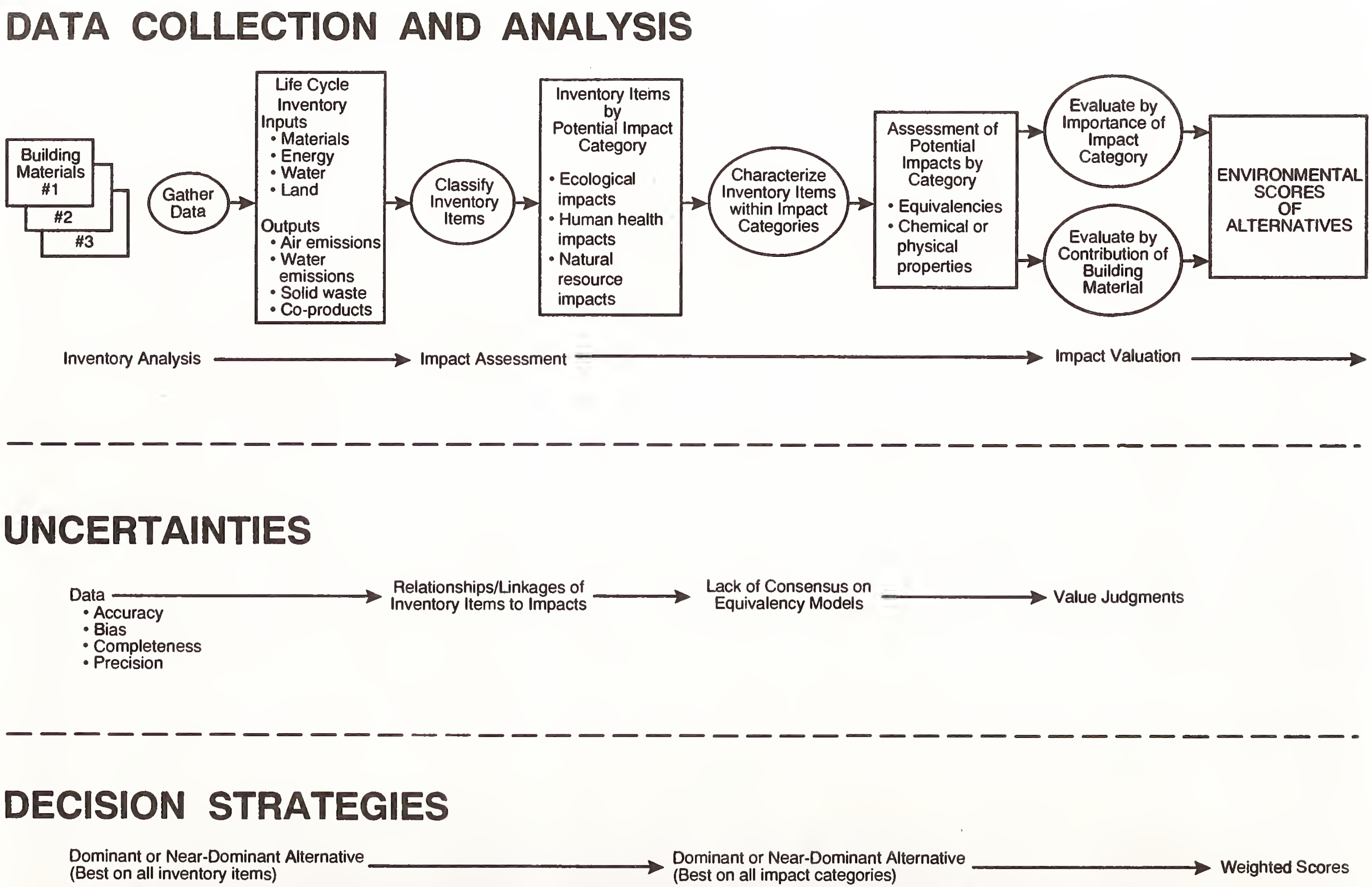
The *improvement assessment* step identifies and evaluates opportunities for making changes in the product life cycle which improve its cradle-to-grave environmental performance. Depending on the goal of the LCA, the improvement step may be omitted. For example, if the goal of the LCA is to select the most environmentally preferable from among three building materials, the improvement step is unnecessary.

NIST is applying the LCA methodology to building materials. In so doing, NIST is adding explicit guidance to the LCA impact assessment and valuation steps. The guidance consists of the following three principles:

> *1) Avoid false precision.* There is some uncertainty associated with the data used at each LCA step, which influences the precision of the final results. It is important to document the precision with which conclusions can be drawn about the environmental performance of building materials. For example, if at the inventory analysis step, sulfur dioxide emissions are estimated within a range of plus or minus 5 percent, then an overall environmental impact score cannot be derived with 100 percent certainty. The NIST methodology avoids false precision by collecting uncertainty data at each LCA step and propagating (accounting for) uncertainty throughout the LCA. The final environmental impact score will thus be bounded by an uncertainty range.
>
> *2) Address scale of impact.* The LCA impact assessment step characterizes the inventory items in relation to environmental impacts. This step will also relate the flows (to or from the environment) occurring during the life cycle of a building material to the total flows occurring at scales such as the United States as a whole. For example, the NIST methodology will relate the CFC emissions associated with vinyl siding's life cycle to the total CFC emissions from the United States, and will use this information in deriving the final environmental performance score for vinyl siding.
>
> *3) Minimize assumptions and uncertainty.* Each LCA step introduces additional assumptions and uncertainty. The NIST methodology minimizes these by checking data after each LCA step to see if one building material alternative shows *dominance* or *near dominance*. Dominance is shown when one alternative performs best on all criteria.

These three principles are implemented in the NIST LCA methodology for measuring the environmental performance of building materials, depicted in figure 1. The goal is to assist material selection decisions by assigning relative environmental scores to a set of building material alternatives. To the extent possible, all environmental impacts will be included. The first step is inventory analysis. Environmental input and output data will be gathered for all building material alternatives on a per functional unit basis, complete with uncertainty ranges. In the (unlikely) event that one alternative performs best or nearly best with respect to all inventory items, that alternative will be flagged as the dominant or nearly dominant alternative. Note that large uncertainty ranges do not preclude dominance as long as there is no overlap among alternatives.

The next step is impact assessment. First, inventory items are classified by impact category. Then inventory items are characterized within impact categories. For many of the impact categories,



Source: The Scientific Consulting Group, Inc.

Figure 1. Measuring the Environmental Performance of Building Materials.

ublished "equivalency factors" are available to normalize the inventory items in terms of rength of contribution [2]. For example, equivalency factors have been developed for each of ie major "greenhouse gasses." These factors indicate the *relative* "global warming potential" f each greenhouse gas, taking into account the different strengths of radiative forcing as well s differences in atmospheric lifetimes [3]. The global warming potential equivalency factors will e used to convert all greenhouse gas inventory data (reported as tons of a given greenhouse gas mitted per functional unit of a particular building material--for example, tons emitted per square ieter (square yard) of carpet) into "CO_2-equivalents" (reported as tons of CO_2 per functional nit). Following this conversion, all inventory data in the "global warming" impact category can e summed to arrive at a scalar total (tons of CO_2-equivalents) to allow direct numerical omparison among building materials.

quivalency factors are subject to some uncertainty based on the strength of the underlying ience. The NIST methodology will attempt to reflect the literature's assessment of this ncertainty by using intervals (ranges) rather than scalar numbers for the equivalency factors. rithmetic operations on intervals are well established [4] and will be used in the NIST iethodology as a basic means for propagating uncertainty throughout the LCA.

or some impact categories and inventory items, equivalency factors have not been published, there is no clear basis for normalizing and summing the inventory data within an impact ategory. In such instances the NIST methodology will allow the user to check for dominance r near dominance of one material alternative over the others. A flexible heuristic method will e available for assigning a summary score to the dominant and non-dominant alternatives within l such impact categories, but the software will also flag these impact category results to indicate iat the relative scores are not based on peer-reviewed, scientific methods for normalizing the iventory data in terms of strength of impact within the impact categories.

he third step in the LCA is impact valuation. At this step, impact assessment results will be ormalized and synthesized into an overall environmental score for each material alternative. Iultiattribute decision analysis (MADA) techniques are useful here [5]. MADA techniques apply problems where the decision maker is choosing or ranking a finite number of alternatives ouilding materials) which differ by two or more relevant attributes (environmental impacts). The tributes in a MADA problem will generally not all be measurable in the same units, and some iay be either impractical, impossible, or too costly to measure at all (as is the case with some nvironmental impacts). Most MADA methods require the decision maker to assign different evels of importance to the different attributes of the problem.

IADA techniques will be used to arrive at overall, relative environmental scores for building iaterial alternatives. The NIST/EPA team plans to conduct workshops in 1996 to collect sets of IADA importance weights for environmental impacts from several stakeholder perspectives (e.g., olicy maker, environmentalist, and building industry perspectives), with input from nvironmental scientists and others. The decision maker may then select that set of importance reights most appropriate for the decision at hand, and may also test the sensitivity of the nvironmental scores to the different stakeholder perspectives.

he LCA is complete after the impact valuation step. Impact valuation yields environmental scores, which are the goal of this LCA application, so the improvement assessment step is unnecessary.

Measuring Economic Performance

Measuring the economic performance of building materials is more straightforward than measuring environmental performance. Standardized methodologies and quantitative, published data are readily available.

The American Society for Testing and Materials (ASTM) Subcommittee E06.81 on Building Economics has published a compilation of standards for evaluating the economic performance of investments in buildings [6]. The single standard most appropriate for evaluating the economic performance of building materials for subsequent comparison with environmental performance is ASTM E 917-93, *Standard Practice for Measuring Life-Cycle Costs of Buildings and Building Systems* [7]. The life-cycle cost (LCC) method sums over a given study period the costs of an investment. The sum is expressed in either present value or annual value terms. Alternative building materials for a given functional requirement, say flooring, can thus be compared on the basis of their LCC's to determine which is the least-cost means of providing flooring over that study period.

The LCC method includes the costs over a given study period of initial investment (less resale or salvage value), replacements, operations, maintenance and repair, and disposal. It is essential to use the same study period for each alternative whose LCC's are to be compared, even if they have different useful lives. The appropriate study period varies according to the stakeholder perspective. For example, a homeowner would select a study period based on the length of time he or she expects to live in the house, whereas a long-term owner/occupant of an office building might select a study period based on the life of the building.

It is important to distinguish between the life cycles underlying the LCA method (used to measure environmental performance), and the LCC method (used to measure economic performance). LCA uses an *environmental* life-cycle concept, whereas LCC uses a *building* life-cycle concept. These are different. The environmental life cycle of a building material begins with raw materials extraction and ends with recycling, reuse, or disposal of the material. The building life cycle of a building material begins with its installation in the building and lasts for the duration of the LCC study period, which is determined in part by the useful life of the material and in part by the time horizon of the investor. While there is overlap between these two life cycles once the material is installed in the building, it is important not to confuse the two. The reason why LCC uses a building life cycle rather than an environmental life cycle is because out-of-pocket costs to the investor are borne over this time frame. It is these costs to the investor upon which financial decisions are made.

The LCC for a building material is computed by discounting all costs occurring over the study period to the present and then summing. The discount rate converts future costs to their equivalent present values and accounts for the time value of money. Discount rate values to be used in Federal projects are legislated by the Office of Management and Budget; these values apply to analyses of private sector projects as well.

Balancing Environmental and Economic Performance

Figure 2 displays how environmental and economic performance are balanced. Suppose a building designer is choosing from among five alternative flooring materials and that each point in figure 2 represents one material's environmental/economic performance balance. The designer will first rule out Alternatives D and E because they are dominated by at least one other alternative, that is, they perform worse than another alternative (Alternative B) with respect to *both* the environment and economics. Of the remaining alternatives, Alternative A costs the most, but offers the best environmental performance. Alternative C offers the best economic performance and the worst environmental performance. Alternative B improves environmental performance (relative to C) at little increase in cost. The designer can now make an informed decision. He or she will select from among Alternatives A, B, and C that which best reflects the relative importance he or she gives to environmental versus economic performance.

Decision Support Software Features

Decision support software is being developed by NIST to implement the methodology described above for balancing the environmental and economic performance of building materials. The software will use as input the database of environmental and economic performance data. Together the software and database are known as BEES. BEES will be available over the Internet, which will offer instantaneous access to the tool as well as instant dissemination of data refinements. Data refinements are expected over time as the state of the art of environmental assessment advances, new building materials arrive on the scene, and the costs of building materials change.

BEES will accommodate different levels of user expertise. It will include built-in, "default" data so that users unfamiliar with LCA may readily make and defend building material selections. Note, however, that BEES will *not* include default values for the relative importance of environmental and economic performance. Rather, BEES will display, as in figure 2, the environmental/economic tradeoffs offered by the decision alternatives. It will remain up to the user to select the alternative that best reflects his or her viewpoint.

The more experienced user will be able to customize the default data. For example, a materials manufacturer will be able to enter proprietary data on their products. Other data, such as relative importance weights for environmental impacts and the discount rate for LCC computation, will also be editable. These users will thus be able to do "what if" analyses to examine how changing the data affects the environmental/economic performance balance.

Finally, BEES will follow the data transparency principle of the LCA methodology by documenting data used and assumptions made at every LCA stage.

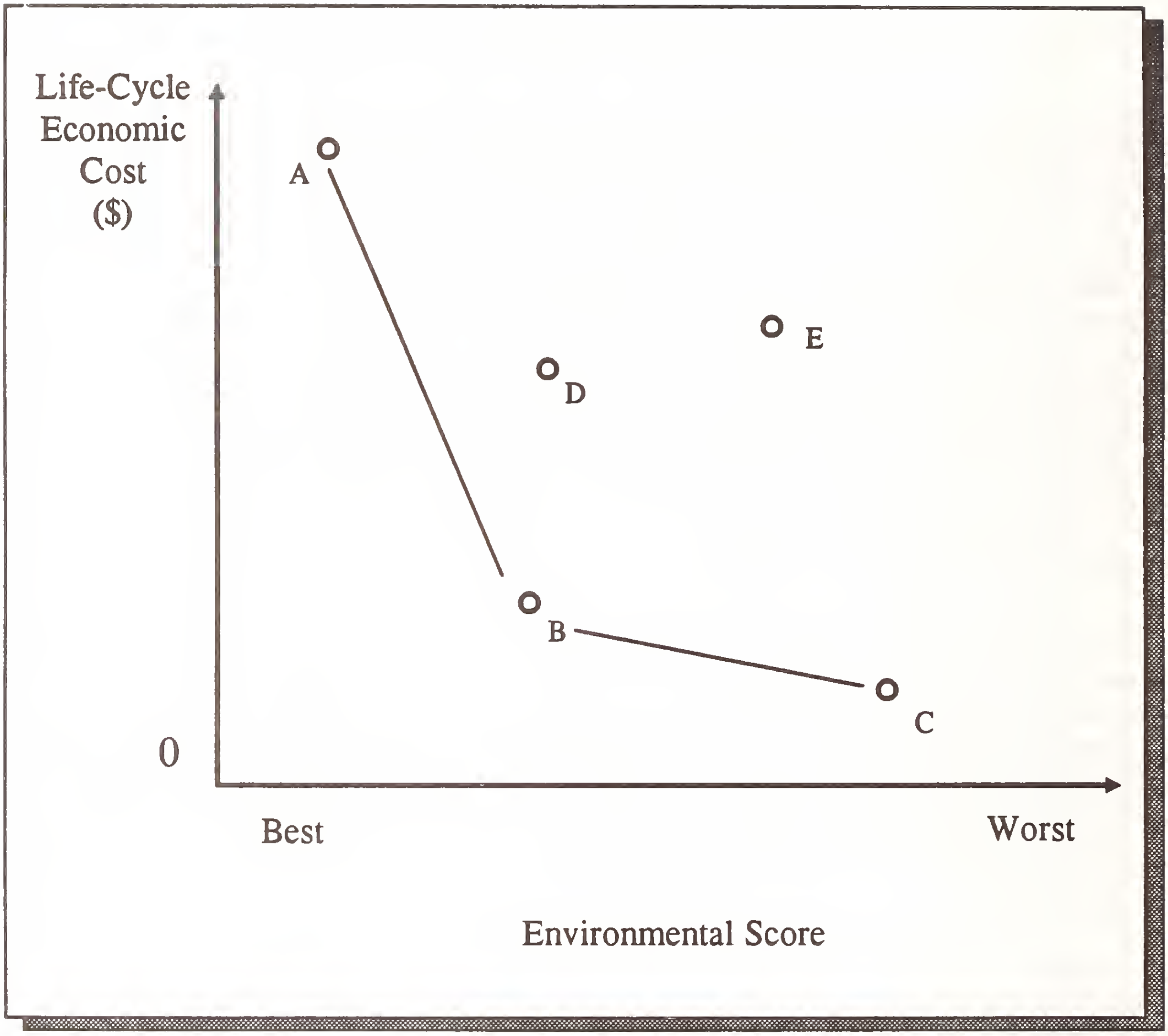


Figure 2. Balancing Environmental and Economic Performance.

Summary

The building community is making decisions today that have environmental and economic consequences. Their decisions are plagued by incomplete and uncertain data as well as the lack of a standardized methodology for evaluating the data. The NIST/EPA team seeks to support these decisions by gathering environmental and economic performance data and by structuring and computerizing the decision-making process. The resulting BEES tool will be publicly available over the Internet.

Acknowledgments

The environmental performance methodology described herein has benefited greatly from the input of the EPA arm of the NIST/EPA team: James White of the EPA National Risk Management Research Laboratory, and EPA contractors Joel Todd and Richard Pike of The Scientific Consulting Group, Inc., Hal Levin of Hal Levin & Associates, and Pliny Fisk of the Center for Maximum Potential Building Systems, Inc. The comments of the EPA team members and NIST reviewers Hunter Fanney, Harold Marshall, and Stephen Weber inspired many improvements.

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Assembling the Design Team to Meet Client Needs

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Abstract: This unique panel discussion focuses on benefits obtained from the team approach to green design and construction, from project conceptualization through development of environmental guidelines, obtaining client involvement, coordinating team members, and establishing checkpoints.

Overview

Good afternoon, my name is Dru Meadows; I manage the Green Team at BSW International, an architectural and engineering firm headquartered in Tulsa, Oklahoma. BSW is a large firm; it has approximately 600 employees in offices in the United States and Mexico. For the last ten years, BSW has specialized in large volume building programs nationally and internationally - Marriott, Albertson's, Wal-Mart, Home Depot, Taco Bell, McDonald's. The inherent nature of these repetitive building programs allows BSW and its clients to work closely together to identify design opportunities, determine the most effective solutions, monitor those solutions, and implement improvements.

One of the most exciting design opportunities we have found is the incorporation of green considerations into mainstream architectural practice. To address these issues, BSW has developed a Green Team comprised of architects, engineers, computer specialists, specifiers, and communications professionals. BSW's Green Team actively pursues a wide range of issues affecting our environment, investigates the environmental impact of building materials and processes, and seeks to incorporate feasible, environmentally-sustainable design solutions into viable building programs. We are expanding beyond architectural services to include site surveys, construction services, building operations/maintenance surveys, and development of corporate options for environmental responsibility.

In many respects, environmental issues parallel efficiency issues. Nature is extremely efficient; everything is raw material for something else. No aspect of the natural world is wasteful ... with the single exception of our own species.

We waste energy: "...every day the worldwide economy burns an amount of energy the planet required 10,000 days to create." (1) The USA is especially wasteful. "If our economy was as energy efficient as that of Sweden or Japan, we would have been spending $200 billion a year less in energy during the past decade, an amount equal to the average annual budget deficit incurred by the federal government." (2)

We waste our natural resources: "More than 50 percent of the wetlands of the contiguous United States were lost by 1990." (3) "Between 1980 and 1990, the average annual rate of deforestation worldwide was approximately equivalent to an area the size of the state of Georgia." (4) The USA generates more waste than any other nation. "Every American consumes about 36 pounds of resources a week, while 2,000 pounds of waste are discarded to support that consumption." (5)

Each day, we produce enough garbage to fill 63,000 garbage trucks, which "lined up...would stretch form San Francisco to Los Angeles (about 400 miles)." (6)

The construction industry alone accounts for approximately 20 percent of the waste stream. The majority of this waste is "clean" waste - that is, scrap materials that have not been used. "Nearly a quarter of all ozone-layer-depleting chlorofluorocarbons (CFCs) are emitted by building air conditioning and the manufacturing processes used to make building materials." (7) The construction industry is also a volume consumer of our natural resources and energy.

The costs of such waste are enormous. Wetlands, for example, play an important role in the purification of water on the planet; forests are critical for air purification and planetary cooling. The loss of these areas is experienced by all of us and yet, to date, there is no method for quantifying such losses. "One way to value the forests as air-conditioners would be to assess the annual energy cost of achieving the same amount of cooling mechanically. If the clouds made by the forests are taken to reduce the heat flux of sunlight received within their canopies by only 1 percent, then their cooling effect would require a refrigerator with a cooling power of 6 kilowatts per hectare. The energy needed, assuming complete efficiency and no capital outlay, would cost annually, $1300 per hectare....A hectare of cleared tropical forest is said to yield meat enough for about 1850 beefburgurs annually, meat worth at the site not more than about $40, and this only during the very few years that the land can support livestock.....the 5 square meters of land needed to produce enough meat for one burger has lost the work of a refrigeration service worth about $65." (8) The Department of Commerce - Bureau of Economic Statistics is developing measures of economic value of environmental assets renewable resources, nonrenewable resources, air quality, water quality; (9) and it is likely that measurements of GNP will be revised to incorporate environmental assets.

However, even by current accounting methods, the costs of environmental waste are significant. Simply installing proper insulation, compact fluorescent light bulbs, and energy efficient appliances will, according to Amory Lovins of the Rocky Mountain Institute, make a house "economically equivalent to a barrel-a-day oil well." (10) And if corporate America would embrace similar energy efficiency measures for lighting, motors, and refrigeration, there is the "potential to save about 75 percent of electricity at an average cost of 0.6 cents per kilowatt-hour." (11) Research performed by the National Energy Management Institute (NEMI) indicates that "improving air quality will provide a high return on investment through productivity gains, health savings, and energy reductions." (12) NEMI estimates that corporate America can save a minimum of 55 billion dollars by implementing IAQ improvements based on current materials and technologies.

Architects, as custodians of the built environment, have an opportunity and an obligation to confront these issues. Often, however, the question is not so much whether a greener, more efficient solution exists, but how to identify it and how to implement it. The expectations of the design and construction industry tend to limit design choices to current industry standards - standards which are not necessarily the most efficient. They also tend to focus attention on problem solving during the construction phase, rather than problem identification during the design phase - further limiting the range of possible solutions. In other words, the materials and systems are often less of a challenge than the process involved to incorporate them.

BSW's experience on green projects has evolved into a "super-partnering / fast-track" approach that we refer to as "GREEN-TRACK."

"Super-partnering" combines proven concepts of teamwork with the goals of environmentally conscious design. The traditional team is expanded to include: building officials; local utilities; manufacturers; community groups; lenders; the developer; contractor; architect; engineers;

owner; building occupant (employee and customer); local, state and even federal agencies. Environmental issues are complex and demand active participation from each of the parties involved in the design and construction process.

Traditional "fast-track" processes are expanded to include resolution of green issues. Although GREEN-TRACK may appear more time-consuming than fast-track, it is not necessarily a more lengthy process overall. It is frequently possible to overlap certain research and design development activities with the preliminary site approval process and information gathering. Further, although GREEN-TRACK may require more time at the front end of a project, it requires much less time at the end of the project. This is an important concept: the cost for doing it right the first time is always less than the cost for doing it right the second time.

By whatever term used to describe it, the process of researching and implementing green considerations for a building is an area of growing interest - and the topic for our panel discussion this afternoon. Our speakers represent some of the various team members. After they address several process related issues, we will open the panel up for general questions.

Introductions

Dru Meadows will introduce panelists:
Laurence Doxsey, City of Austin
Diane Morrison, Southern California Gas Company
Leslie Shankman-Cohn, eo designs
Ross Spiegel, Michael Shiff and Associates
Bob Rench, Bank of America

Topics

- Although some progress has been made towards qualifying and quantifying the "greenness" of buildings - Austin, Colorado, USGBC, BREAM, BEPAC- there has been exceptionally little progress made towards qualifying green "expertise." Certainly, a knowledge of environmental issues and principles is an asset in any team member. What green expertise do you look for? how difficult is it to find?

- The project architect or engineer traditionally has been the primary consultant. When teams were developed, the project architect or engineer orchestrated the efforts. Is this team structure applicable to "green" teams? how does the profile of the team change? the interactions?

- Environmental concerns in the 1970s translated primarily into energy conservation efforts; but, those efforts were short-lived. Today, environmental concerns also seem to focus on energy - EPA programs, utility rebates, new ASHRAE standards. How has the design process changed - if it has - to incorporate energy considerations more thoroughly? Comment on the procedures for monitoring? the benefits?

- A common perception of green architecture is that is much more costly than conventional design. What is the cost impact of a green approach to schedule and to materials/systems selection? How can the cost impact be minimized?

- Much of current contractual language seeks to identify relationships and responsibilities of the various parties in terms of liability. The team process we are discussing assumes a less confrontational process and yet addresses issues of potentially significant liability. Please comment on liability issues? ADA - Biochemically handicapped?

• Design and construction industry is especially standards oriented. It relies on building codes and independent product testing to determine acceptable minimum quality levels. Yet, there seems to be a lack of appropriate standards for green systems and products. Is this an accurate perception? If so, how do you deal with the lack of green standards?

• Prior to the industrial revolution, environmental considerations heavily impacted design and construction. Since then, green concerns have experienced only limited recurrence. Will the current interest in environmental issues have a significant impact on the design and construction industry? what is the future of green architecture?

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ENERGY RESOURCE CENTER:
Assembling the Design Team to Meet Client Needs

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Abstract

One of the world's foremost examples of sustainable design is found in Southern California Gas Company's new Energy Resource Center (ERC), opened early in 1995 a short 20-minute freeway drive southeast of downtown Los Angeles in Downey, CA. The center incorporates the latest technology in energy efficiency, resource conservation and environmental sensitivity. The building, itself, and its ongoing programs help energy decision-makers of all kinds.

Who and what were involved in creating the ERC's sustainable design? It goes beyond detailed processes or improved technology, although they are certainly a part of the story. To succeed, sustainable design needs to include people working as a team with a common overarching goal. Without peoples' cooperation and commitment, affordable energy and environmental advancements would remain an unfulfilled ideal. In sustainable design, the desired end-product and the creative energy of conception must come together at the very start of the work project, and stay together throughout the life of the project.

Throughout more than two years of work, the ERC design team developed an extraordinary amount of coordination and cooperation. A lot of management skills were invested in this collaborative teamwork, using the skills of each specialist while at the same time breaking down the traditional barriers to collaboration among those same specialists. Traditionally, architects and engineers have had limited interaction; engineers and interior designers even less. In pursuing sustainable design, we could not afford to let these separations exist.

A multi-disciplinary approach was applied. Ideally, in a sustainable design project, all of the key team members participate throughout the project, not just at junctures where their particular specialties are being applied. Each member has to operate, in effect, as both a specialist and generalist.

As a result, the ERC structure, itself, is recycled from a previous gas company administrative office complex dating back to the late 1950s. Instead of demolishing the old building, it was carefully dismantled and then reassembled or recycled. Approximately 62 percent of the old building was used in the ERC or recycled elsewhere. The building has been designated by the U. S. Environmental Protection Agency as an "Energy Star" structure, and it exceeds California state energy commission Title 24 standards for new buildings by 45 percent.

To assemble the ideal team to accomplish the stretching goals of a project such as the ERC, the keys are: (a) extreme flexibility by each of the team members, (b) a willingness to develop new paradigms, (c) involvement by everyone from start to finish, and (d) a shared vision of the final product.

I. Introduction

The ERC did not begin as a sustainable design project. As its mission and focus crystallized over a one- to two-year period, the center's plans evolved into sustainable design. In 1992 when the first concepts were shaped, the center was focused broadly on all "core" customers, with an emphasis on the impact of increasingly more stringent air quality standards as they related to the use of natural gas. The 1990 congressional amendments to the national Clean Air Act and the U. S. Presidential political campaigning added to this emphasis.

At that time, the ERC was not a building, but rather a program that over three distinct phases would result in a facility being developed in the third phase. Before that, some discrete energy-management services would be developed for customers: (1) an air quality compliance "telephone hotline," including outreach to customers and a measurement of their response to the service; (2) detailed consumer information and education on air quality compliance options; and (3) a full-service ERC-type facility, focused on air quality. Roughly, a half-million-dollars was budgeted for the information hotline service, almost $4 million for the consumer information/education campaign, and $13 million for the facility.

The mission envisioned for the center at that time was: "meeting the information and educational needs of core customers as well as enhancing the company's competitiveness."

Early in 1993, these plans were refined further to concentrate more on developing a facility in the 30,000-square-foot range. It would be designed and constructed in traditional company fashion: a cross-functional project team would be formed to plan, monitor and control all of the work. In addition, an "advisory team" was contemplated to provide the project with an "external" perspective on regulatory, environmental and energy efficiency issues.

After another six months--mid-1993--the project moved to the fringes of sustainable design when a decision was made to remodel an existing Southern California Gas Company facility in Downey, CA, located about a 20-minute freeway ride southeast of downtown Los Angeles. The remodeled former administrative office complex would open June 1, 1995 on a two-year planning/construction schedule, and with a $10 million budget.

The mission was narrowed to focus on providing commercial and industrial customers with cost-effective and energy-efficient solutions to their business operating requirements. At the same time, the facility was expected to serve as a showcase for the company and a knowledge center--both through the building's built-in features and the exhibits and programs that take place within the center.

The timetable established at first called for design and planning during the last half of 1993; demolition/relocation the end of 1993 and the first quarter of 1994; and construction through April 1995. In reality, it was not until the summer of 1994 that design was completed and construction began. In the fall of 1993, the emphasis for sustainable design developed, gaining momentum from an environmental consultant who was added to the advisory and project teams.

II. ERC Project Team

In approaching the ERC as a sustainable design project, there was a conscious effort made to form a working group that was more than the traditional task force or smooth-functioning work group. There was a desire to form something more than a loosely bound together confederation of "experts." Although the phrase may be overused in today's business environment, a "high-performance team" is what was sought. True teamwork and the synergy developed from it is what The Gas Company tried to create. In this regard, once the vision for sustainable design was articulated, there was a concerted effort made to match the desired end-product with the individual and collective creative energy of the team. A full-time gas company project manager was assigned the responsibility for making this happen.

An engineer with extensive commercial/industrial marketing experience in the gas industry, Tony Occhionero, was selected to manage the project--even before it evolved into sustainable design. To fill his project team, Tony identified eight other positions: (1) company construction manager, (2) architect, (3) construction company representative, (4) interior designer, (5) environmental consultant, (6) energy efficiency consultant, (7) indoor air quality consultant and (8) local government representative.

The Project Team as a whole met regularly. It began meeting every two weeks and later each month prior to construction. During construction, it met weekly, although not all members were able to attend every meeting. And various subgroups worked weekly, if not daily, on the center. They all recognized from the beginning that they were part of something very special--a project that would shatter existing paradigms and help form new models to replace them.

To provide an oversight and "policy" perspective, a 26-member advisory panel was created, including several of the project team members, Occhionero being one of them.

III. ERC Advisory Panel

Despite our best efforts, large, mature companies such as Southern California Gas Company have institutional "blind spots" directly proportional to their relative size in their market(s). As the nation's largest gas distribution company, SoCalGas has had a tradition for being very confident and insular in its attitudes and outlook. But in the face of new global competition, that is rapidly changing. The use of an advisory team composed mostly of outsiders to oversee the ERC's development is a current example that the company is loosening up and reaching outside its internal resources and its industry more often these days.

The philosophy behind the ERC was that it should be state-of-art, flexible and ever-changing. It was hoped that by bringing in a potpourri of people from various fields in the public, private and academic sectors, the future could be built into the center. The intent was to have the advisers help make the ERC forward-looking and innovative, not only in its structure (or "shell"), but also in its evolving programs for future energy decision-makers.

Thus, from the public sector there were representatives from federal EPA; state utility and energy commissions, respectively; regional air quality board; and local government (the city in which the ERC resides, Downey, CA). From the academic community, there were architecture and engineering representatives. And from the private sector, in addition to gas company project team members, marketing, research and general management representation, there were external project team members, and experts in interior design, lighting design, energy efficiency, environmental planning, construction design, display and office design.

The advisors met monthly at first and bimonthly as the project progressed. They offered detailed reactions to the plans and implementation as work moved forward. The advisers stopped meeting in early 1995 when the center opened, however, recent de-briefings by the Project Team have surfaced the idea of keeping advisors on board in some form as the ERC matures and evolves. In fact, some suggest including a series of advisory teams to cover various aspects of the ERC. For example, if it is to become a national and international knowledge center with "information" as its product--not energy, per se--advisors from the information technology fields might be appropriate. Similarly, if the center is a one-stop resource for the latest air quality permitting information, perhaps a team of advisors from the fields and industries working most directly on air quality issues should be formed?

IV. Owner's Leadership Role

As SoCalGas' innovation and openness have changed in recent years so has its philosophy and vision. The ERC is a living example of that. Since it first surfaced as a bare concept in 1992, until the careful dismantling and recycling of an existing company office facility began in the spring of 1994, the company leadership's thinking about the

ERC took many twists and turns. It was first viewed as a company resource for addressing the growing issue of air quality and its impact on the combustion of fossil fuels. By the time the dismantling/recycling began the center's focus was to create a customer resource that could become a bold statement about the future of building and energy technology and their economic and environmental impact.

The Gas Company during this time was in the process of transforming itself through extensive changes in its structure and operation. Part of that transformation was the identification of a company vision that put the company's entire focus on customers and becoming a world class energy service provider. In this regard, a new icon for SoCalGas has been established at a very time when the company is in the process of reinventing itself--top to bottom.

As part of the ERC's development, the company put its commitment in writing in an "environmental project manual." Hopefully, the center, itself, and what we do with it, will continue to reinforce our living up to that commitment. That commitment includes:

- Maximizing energy efficiency and environmental gains.
- Implementing sound waste management practices through source reduction, recycling and safe disposal methods. Eliminating hazardous substance use.
- Using ecological criteria to make procurement decisions.
- Encouraging commuting alternatives for workers at the construction site.
- Strict adherence to all environmental protection laws.
- Use of environmentally sound building practices.
- Foster the support of contractors' and subcontractors' employees for environmentally sound building practices and materials. (Eventually, many subcontractors "caught the spirit" of sustainable construction. As a result, many of the workers were making suggestions on their own initiative on how to do things in a more environmentally sensitive manner during construction.)

V. Contractor's Commitment

In selecting a contractor for the ERC, there was an "environmental" litmus test. Each bidder had to describe their philosophy and track record on integrating environmental safeguards into their projects. There was only one clear winner in this regard and that was the construction company that was selected, Turner Construction Co., which wasn't the absolute low bidder. Several bidders made recommendations to cut corners to eliminate environmental aspects in the ERC. One even suggested that the company ignore the environment in building the ERC.

On the other hand, Turner Construction had an environmental track record. It had a commitment. And since its involvement with the ERC, it is devoting an entire sub-segment of its business to environmentally sensitive building practices. So, it was easy for Turner to not only commit to, but help write its part of the public commitment in the ERC Project Manual. That commitment included:

- Promoting the owner and architect's efforts to create an environmentally sensitive structure. Environmental considerations range from site demolition/excavation to managing, recycling and disposing of solid waste resulting from the demolition and construction of the ERC.
- Implementing a program to divert demolition and construction waste from landfills. (This was accomplished economically with minimal interference by subcontracting a waste hauler on the project that separated the materials at their own yard for redistribution to another end-user.)
- Reuse of construction waste materials such as concrete, drywall, wood, steel and others.
- Submitting an environmental policy statement and a summary of environmental practices relevant to the ERC (for the construction company).

VI. Environmental Project Manual

To help implement the commitments of both the owner and the construction company, the ERC environmental adviser, John Picard, developed a detailed "project manual," a one-inch thick catalogue of various products and services that are resource conserving and environmentally sensitive. Broken down into great detail, it has some of the consultant's information and a lot of manufacturer and/or supplier information on these "green" materials and products.

The manual provided the project team with detailed information on processes, materials and vendors. Various "environmental alternatives" were outlined, providing a real world "working" resource to help achieve environmental goals in both the building process and in the operations and maintenance of the new facility.

After an introductory section, with the commitments of the owner and construction company among other things, the manual provides guidelines for the dismantling, recycling and construction of the ERC. There are sections on: demolition, earthwork, paving/surfacing, irrigation, site furnishings. Following that are 14 sections categorizing equipment and materials as follows: concrete, masonry, metal work, wood/plaster, building envelope, doors/windows, finishes, specialties, equipment, furnishing, special construction, conveying systems, mechanical equipment and electrical.

VII. Commissioning

An experienced firm has worked closely with the ERC in performing the necessary analyses to make sure the facility is fulfilling its promise for energy efficiency and environmental sensitivity. The firm of Robert Bein, William Frost & Associates is doing the so-called "commissioning" of the building, which is still being completed in these first eight or nine months of operation. The consultant's analysis includes the development of a computer model of the facility using the DOE-2.1E building energy simulation program, which was used in the design and planning of the center.

Commissioning helps verify that each building system performs according to its design intent. It strives to accomplish this by: (1) documenting the design, construction and operation of the building, (2) directing the performance testing of building systems, and (3) training building staff in the correct operation and maintenance of the building. Commissioning is an emerging field that has proven to be an effective way to ensure that building systems operate correctly, giving the expected performance levels.

Generally, the formal building commissioning process can result in both greater comfort and energy efficiency. Additionally, building systems that are properly commissioned often operate for a longer period of time with fewer maintenance problems.

As one of 25 buildings nationally that have been selected for the U.S. EPA's "Energy Star" Program, the ERC has been recognized for having been retrofitted with energy-efficient technologies that allow the building to significantly exceed the previous facility's level of energy-efficiency. As part of the commissioning, the gas and electric use in the new ERC has been analyzed in detail and compared with similar energy use in the previous facility. Because of significant changes in square footage and space configuration in the recycled, new facility, the consultants had to make various assumptions about the heating, ventilating, cooling systems (HVAC) that operated previously.

The consultant has obtained detailed results in its energy analysis, including intricate descriptions of the ERC's major building systems, which include a combination HVAC system using four separate, but compatible, types of equipment. The consultant also documented the assumptions that were made as part of the analysis. Their on-site verification of equipment installation and operation involves pre-functional and functional testing of all components in the building mechanical systems. This ensures that they were installed correctly and operate properly. Deficiencies are reported and rectified.

Ultimately, the consultant submits a written report detailing the entire commissioning process. The consultant also oversees the preparation of the operating/maintenance (O&M) manuals for all equipment and documents the training of the building's O&M staff. This helps assure that the building will be properly operated and maintained, and provides a written record of the initial operating parameters established for the building's systems.

The ERC commissioning eventually will verify what computer models already have indicated: namely, that the facility exceeds the energy-efficiency of the previous building, as well as California's Title-24 energy-efficiency code for non-residential buildings, by at least 45 percent. Thus far, computer models have shown that the per-square-foot energy use on an annual basis has been cut almost in half in the ERC. Ongoing work will be done to make sure the facility continues to operate as designed with this level of energy efficiency.

VIII. Conclusions

Sustainable design requires a high performance team, with each individual team member willing to operate as both a specialist and generalist over the entire life of a project. It also requires a collaborative approach. And, finally, it requires flexibility on everyone's part, an openness to new ideas and a willingness to try new approaches.

A new mindset and a high level of commitment are required for the team members. That applies to both project team members doing the hands-on work and advisers providing oversight and counsel. Ultimately, this requires a strong public commitment from both the owner and constructor of a sustainably designed project.

In Southern California Gas Company's Energy Resource Center, the various team members embodied these principles. They helped nurture a vision, stayed flexible throughout its planning, design and implementation, and applied common sense and innovation. The testimony to their efforts is a 45,000-square-foot structure that serves as a new model that others can replicate.

RESPONSIBILITY FOR A SUSTAINABLE ENVIRONMENT

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Good evening.

First I want to say how pleased I am to be a part of the 2nd Annual Green Building Conference. Also, I would like to extend my appreciation to the U.S. Green Building Council, and our hosts, Montana State University for making this happen. I can't think of an environment more suited to the discussion of environmental issues. Surroundings like Big Sky truly brings the need for the co-existence of nature and industry into perspective.

This conference brings together a most unique collection of people. There are representatives here tonight from government, business, industry, academia, design, facilities mangers, property owners, and professional architects like our friend Bob Berkebile with whom our company has interacted and supported in his efforts with the AIA/EASE project.

We are all here for a few days with a common interest albeit with different perspectives. Our mission during this conference extends far beyond these three days, but rather involves a long-term commitment on behalf of the people in this room, business, and society in general. The challenge is to collectively take responsibility for the protection and preservation of our environment. To be successful we must each do our own part, and we need to encourage others to be committed and involved.

I reflect back on the experience of our own company.

Collins & Aikman's interest in environmental initiatives began several years ago through listening to our customers. It was apparent that the environment was an emerging issue. However, initially we couldn't determine its magnitude. Were companies being serious or emotional? Were environmental solutions "NICE TO HAVE" or "ESSENTIAL?" Did this transcend conversation to a meaningful corporate commitment from the top? Certainly, there were a lot of unanswered questions. During our assessment, we talked to numerous people to include CEO's and experts in the field. We asked our marketing and technical people to investigate environmental opportunities. Throughout the evaluation process, the most profound response came from a friend who said, "If you want to predict the future of the world talk to the children. The future will then be clear." An important market segment for our company happens to be the education market. Our dialogue with educators brought the importance of the environment into focus. The overwhelming message is that we have to change the way we live, the way we produce, and the way we co-exist with nature. Clearly, environmental issues are here to stay.

It is time that industry views the environment as an opportunity, not as a burden. At Collins & Aikman we felt that if we could provide environmental solutions it would not only be the right thing to do, but would be a strategic competitive advantage for our company.

However, environmental stewardship does not just happen. It's not a matter of flipping a switch. The first thing we had to do as a company was make a total commitment. We had to change the way we think. We had to challenge basic assumption. We had to employ non-traditional thinking to break traditional paradigms.

There is typically a lot of fear associated with being or becoming "green." We must all break the paradigm that environmental stewardship is costly, restrictive and burdensome, but, rather, environmental responsibility is necessary to protect the quality of life for future generations.

So, where and how did we start?

Our primary objective was to determine where we were and where we needed to go. How do we do it? We decided to get some totally objective opinions. I'll never forget the day that we brought together leading architects, whom we had never met, to make an environmental assessment of our company. What could be more frightening than to have people like Kirk Gastinger, then chairman of the Committee On The Environment, Paul Bierman Lytle, Gail Lindsey, Dagmar Epsten and Bill McDonough, analyze your business from an environmental point of view. This expectation was like anticipating being strip searched. Not very comforting.

After a day and a half of discussing topics such as indoor air quality, asbestos, recycling, radon, total emissions, energy, lifecycle and sustainable design, we had to ask the dreaded question: How are we doing?" I'll never forget Bill McDonough's reply, "Frankly, I'm very disappointed ..... disappointed that you are not a bigger part of your industry because if all companies are doing what you are, the world would be a better place."

For us, that was a great beginning.

A few years later, we are taking full responsibility for any product that we have ever made by reclaiming it and manufacturing 100% recycled value-added products. Today, our recycling program is a commercial free-standing profitable business. We warranty that no portion of our product which we reclaim will ever be introduced into a landfill or incinerated .... EVER! By this time next year, we will offer our existing product with 80% recycled content while maintaining our strict guidelines for product performance. We have also committed to the study of the feasibility of a "zero" emission manufacturing plant.

I've taken this time to relate our story to demonstrate that it can be done and done profitability without government funding or mandate. I would also say that any other company determined to make a commitment could have a parallel experience. However, while we have achieved a great deal, which we are very proud of, we have a long way to go. And, we remain totally committed.

The challenges that lay ahead for all of us are numerous. Our primary challenge, however, is quite clearly defined. We must conserve our natural resources in order to protect future generations. Broadly defined we must create a sustainable environment. Our own company is 150 years old. For it to be viable for the next 150 years we must take important steps now.

As a manufacturer in pursuit of environmental stewardship, we have identified three critical issues that we believe are important for every manufacturer to consider as they examine their products and plants. They are:

- Design
- Manufacturing
- Reclamation

DESIGN

Without question, the essence of sustainability begins with Design. It is our responsibility as manufacturers to engineer products for a longer lifecycle; therefore, preserving natural resources and conserving energy. Of course, longer lifecycle also minimizes the need for disposal. We also have to accept the challenge to produce products using fewer natural resources. Finally, imperative in this design process must be consideration for what happens to products after their useful life.

MANUFACTURING

In our manufacturing process we must change the way we produce, and expect more from our vendors. We must demand from our vendors materials that are free from harmful chemicals; therefore, eliminating them from our products and the waste stream.

Further, we must manage or eliminate all waste. Plant waste and emissions must be converted to food for other useful products.

We must also think beyond the elimination of just solid waste and address all plant emissions much as John Todd has described in his work Living Machines. The goal of every manufacturer must be zero emissions.

RECLAMATION

Manufacturers must ultimately take full responsibility for the reclamation of their own products after their useful life. I believe that one or all of the following must happen:

- Products must be engineered for down-cycling so that they can be recycled into other useful products.

or

- Products must be engineered to be recycled back into themselves (true recycling)

or

- Products that have to be disposed of must be biodegradable. I do not believe that incineration represents a plausible solution to environmental problems.

We simply can't continue to dump non-biodegradable waste into the earth for the future generations to deal with. Paul Hawken, author of the Ecology of Commerce defines this concept as "cyclical economies" where everything we produce is either fully used or reused and then returned to the system to be used again and again and again.

I've outlined for you the perspective of one company as it relates to our philosophy of sustainability. I believe that many great companies such as Dow Chemical, DuPont, U.T. Carrier, Herman Miller and others have great, innovative programs to address these many issues. I applaud these companies for their proactive initiative to evaluate lifecycle, recycling and full cost accounting practices.

Our environmental focus is not, however, free of problems. Some issues are very troubling to me, as we move through this environmental journey. One is the proliferation of "green marketing" or as some term it "green wash." Some companies are making environmental claims that would not stand up to peer review in this audience. They are making claims without substance. I submit to you that this rush "to claim" undermines the seriousness and the legitimacy of our movement. I consider this unrestricted license to claim very dangerous.

If companies are allowed to profess environmental claims without accountability then neither they nor anyone else has incentive to provide real solutions. Further, if challenges to these claims come only from outside organizations, then the credibility of even the most responsible companies is jeopardized.

It is with this thought that I believe that we must set achievable, objective, meaningful standards to create a structure for environmental claim assessment. This structure should include an audit to certify conformance of claims. I salute the efforts of the U.S. Green Building Council for the development of its Resource Center and the Green Building rating system. If properly executed, this effort can be a profound beginning. Also, I have to believe that the government agencies such as DOE, EPA, DOD, GSA, ASTM, CSI and Public Technology, Inc., as well as other federal and state agencies can make a significant contribution to support this cause.

Lastly, it is critical for each of us to do our part to maintain our commitment to environmental solutions. We must be involved to do it right. One of our many challenges is to educate the consumer. We need to raise the level of understanding and support for the importance of environmental responsibility. As leaders, we each play an important role. Manufacturers can be diligent and committed, but if the consumer doesn't appreciate the importance it will die. A start would be for companies to do business with companies that are environmentally progressive ...... to support each other. As an example, I am pleased with the efforts of the Buy Recycled Business

Alliance (BRBA), where companies of all sizes are promoting the purchase of products that are recyclable or have recycled content. Companies supporting each other in this way can make a dramatic statement to all businesses.

Finally, we must listen carefully to the visionaries propelling this movement and heed their guidance. The passion and commitment of such people as Bill Browning, Amory Lovins, Bob Berkebile, Paul Hawken, John Todd, Bill McDonough, and others must be supported. We can all learn from their very clear understanding and perspective as to how nature and industry can co-exist. Industry must listen and then respond with its resources to make it all happen. With this, the world will be a better place for generations to come.

THE JOURNEY FROM THERE TO HERE
THE ECO-ODYSSEY OF A CEO

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Let me begin by confessing that I don't know what I am doing here this morning. Oh, I know I'm here to make a speech; but why me? What am I doing here?

This is, largely speaking, a young audience - certainly younger than I. I grew up in the era of Roosevelt and Truman, and graduated from Georgia Tech the year Eisenhower completed his first term as President. There was a saying in those days that those three presidents, collectively, had redefined the presidency. Roosevelt had shown that a president could serve for life. Truman had shown that anyone could be president. And Eisenhower had shown that the country could get along without a president.

Today, I guess I identify most closely with Truman, proof that anybody can address the Green Building Conference. So, since I can't really tell you why I am here, let me try to tell you about the route by which I came to be here.

Please forgive me if I stay on a personal note for a while longer. I am a product of the post-war era which was, of course, one of enormous prosperity and economic opportunity. I graduated from Georgia Tech in 1956, and spent the next 17 years preparing myself (mostly subconsciously) to become an entrepreneur. In 1973, I cut the corporate umbilical cord (I was 39 years old and had a very good job with a major corporation), and I founded a new company to produce, of all things, carpet tiles - just then beginning to be used in office buildings, where the electrical wiring was in the floor, the furniture was open plan systems furniture, and the office was becoming computerized - known in those days as the "office of the future". The office of the future needed carpet tiles. The new venture was an entrepreneur's dream: beginning with an idea, adding the equity capital including my own life's savings and the investments of friends, arranging the bank debt, acquiring a site, building and equipping a factory, securing raw materials in a time of extreme scarcity, developing and producing products, and launching a sales and marketing effort in the teeth of the worst recession since 1929 - and surviving.

And then prospering, beyond anyone's wildest dreams. Today that company is global. We produce in 22 manufacturing sites, located in the U.S., Canada, the U.K., Holland, and Australia; are building a factory in Thailand; and sell our products in more than 110 countries. Our sales this year will likely exceed $800 million. We make and sell 40% of the carpet tiles used on earth, and enjoy the largest market share in nearly every one of those 110 countries; plus commercial broadloom carpet, textiles, chemicals, and architectural products.

For 21 of our 22 years of existence, I, for one, never gave one thought to what we were taking from the earth, or doing to the earth, except to be sure we were in compliance and keeping ourselves "clean" in a regulatory sense.

True, we had had, developing for fully 10 years, a program called Envirosense®, which had been focused on indoor air quality and alleviating Sick Building Syndrome and Building Related Illness. This effort had been based on some proprietary chemistry we had acquired in the field of anti-microbials, called Intersept®. Intersept is an additive which, if incorporated into plastic materials, will render the surface of those materials self-sanitizing. So materials such as carpets, paints, fabrics, air filters, and HVAC duct liners and cooling coils could be made to be more hygienic and could lead to better quality of air, i.e., reduced bacterial and fungal counts, contributing to healthier indoor environments.

More than 30 companies have joined the Envirosense Consortium (itself, a non-profit educational effort), many of those companies incorporating Intersept into their products under license from Interface, all with the profit motive in mind to be sure; that is, making a buck by selling their products or services to solve a problem, a real and important problem. Envirosense had been and still is an external, market-focused program. And it is accomplishing good things in the field of IAQ.

But then, about a year ago, the president of our research arm, Interface Research Corp., organized a task force, with representatives from all of our businesses around the world, to review Interface's company-wide environmental position. And he asked me to make the keynote remarks, to kick off the meeting and give the group an environmental vision. Well, frankly, I didn't have a vision, but finally I very, very reluctantly accepted his invitation to speak to the new task force. I sweated for three weeks over what I would say to that group. And then, through pure serendipity, somebody sent me a book: Paul Hawken's The Ecology of Commerce (1). I read it and it changed my life. It gave me a vision and a powerful sense of urgency. In making that kick-off speech, I incorporated many of Hawken's examples of what's happening to the eco-system:

1. The reindeer of St. Mathew Island to illustrate carrying capacity, overshoot, and collapse.

2. The depletion of the Ogalala aquifer and the implications of that, namely famine.

3. The loss of 25 billion tons of topsoil every year, equivalent to all the wheat fields of Australia.

4. The usurpation of a disproportionate share of Net Primary Production by the human species, moving toward overshoot and collapse for thousands, maybe millions, of species. "The Death of Birth", as Hawken calls it.

5. The loss of tropical forests to raise soybeans to feed cows in Germany to produce surplus butter and cheese that piles up in warehouses, and a million displaced forest people living in squalor in Rio de Janeiro.

6. The alarming increase in the rate of species extinction, deaths by pesticide poisoning; and so on.

I borrowed his thoughts shamelessly. And I bought in completely to his main theme, that business and industry, the largest, wealthiest, most pervasive institution on earth, must take the lead in saving the earth from man-made collapse. I gave that task force a kick-off speech that, frankly, stunned them and then galvanized them into action, and through them, our whole company, to step up to our responsibility to lead.

I shared with them my vision, inspired by Hawken: Interface, the first name in industrial ecology (worldwide). I gave them a mission: to convert Interface into a restorative enterprise; first to reach sustainability, then to become restorative by helping others reach toward sustainability, even our competitors. Becoming restorative; i.e., putting back more than we ourselves take. And I suggested a strategy: Reduce, reuse, reclaim, recycle, (later we added *redesign*), adopt, advance, and share best practices. Develop the sustainable technologies and invest in them when it makes sense. And I challenged them to pick the year by which Interface would achieve sustainability. Two days later they told me their target year, the year 2000. I'll be 66 that year, and hope to live to see it happen. We gave this program a name, EcoSense®.

We also coined a word, "PLETSUS®", an acronym for Practices LEading Toward SUStainability, and we began to share PLETSUS ideas, internally and externally. You can go into Interface's home page on the Internet and find EcoSense and PLETSUS ideas, right there for you and the rest of the world to see and use. Feel free.

EcoSense is basically, however, our internally focused effort to do what's right. But, it's not just the right thing to do; it's also the smart thing for a manufacturing company that is 100% dependent on a non-renewable resource, petroleum, for its raw materials.

I made other speeches in the months that followed, patterned after that kick-off address. Following one of those, given to a group of Georgia Tech alumni and faculty, one of the professors in the audience sent me a copy of Daniel Quinn's book, Ishmael (2). I read it, then read it again. I've read it five times, now. I'm here to tell you that Hawken and Quinn, together, will not only change your life, but make you understand why. If you haven't already, read Ishmael to understand why the world is in a mess. Hawken will tell you what; Quinn, why.

I continued to read, going back to Rachel Carson's Silent Spring (3), Vice President Gore's Earth in the Balance (4), Beyond the Limits (5), by Meadows, Meadows, and Randers, Vital Signs 1994 (6), and others.

In another life-changing experience, I met and came to love a fellow named John Picard. John is an environmental consultant. He's so smart and knowledgeable and so practical and aggressive at the same time about what's realistically doable. John was consultant to the Southern California Gas Company's Energy Resource Center building project (the ERC). Tony Occhionero was ERC project manager for the Gas Co. I think Tony has already told you about the ERC. It's a landmark building, and John Picard's influence can be seen all through that building. We worked with John and Tony to devise the first-ever in the history of the world (to my knowledge) "Evergreen Lease®" for carpet. In the Evergreen Lease, Interface, the manufacturer, not only made the carpet, but we also took responsibility for installing the carpet, and maintaining it, and because it is free-lay carpet tiles, selectively replacing worn and damaged areas, one 18" square at a time, and implementing a sort of rolling, progressive, continuous facelift by periodically, over the years, replacing modules; and most importantly recycling the carpet tiles that come up. Title for the carpet tiles never passes to the user; it stays with us, the manufacturer, along with the ultimate liability for the used up, exhausted carpet tiles. The Gas Company pays by the month for color, texture, warmth, beauty, acoustics, comfort under foot, cleanliness, and healthier indoor air (Intersept is built in). We deliver these benefits but continue to own the means of delivery - theoretically for as long as the building stands.

Here's the thing: The economic viability of the Evergreen Lease for us depends on our being able to recycle used face fiber into new face fiber, and used carpet tile backing into new carpet tile backing; and we have yet to learn to do either economically. So, you might say, we're cantilevered a bit. But we will get there. It's key to achieving sustainability, along with developing benign energy sources to drive our production processes, and eliminating waste throughout our process. If we can get it right, closed loop recycling, benign energy sourcing, and waste elimination, we might never have to take another drop of oil from the earth. We'll spend the rest of our days harvesting yesteryear's carpets and other petrochemically derived products, and recycling them into new materials; and sunlight or hydro, into energy. That's the vision.

The Evergreen Lease is a manifestation of what Paul Hawken and Bill McDonough have called "licensing". It's the future. We're grateful to the ERC and John Picard and Tony Occhionero for driving this concept to a reality, and letting Interface be a participant. I'll add this footnote: For the Evergreen Lease to become broadly successful, not only must we master closed loop recycling, but the financial institutions must get outside their boxes, too, and become third party participants in this strange concept they never saw before.

I also met Bill McDonough, finally, after hearing about him for years. He's a visionary architect. He approaches everything, even the ecological crisis, as a design problem. We're working with him in our textile business and our carpet business to execute some of his design solutions in product form.

During the year, I've continued to read. A friend took issue with me and disputed Hawken and Lester Brown and others as "alarmists". We have a friendly debate going. He sent me Bast, Hill, and Rue's book, Eco-Sanity (7). It's the other view. It says good science doesn't support the alarmists' views; that the world has 650 years supply of petroleum, not 50; that the concern over the ozone layer is misplaced and unfounded; that acid rain is a disproven theory;

that global warming is, too; that problems with automobiles, nuclear power, and oil spills are past problems that are nearly solved; that pesticides and toxic chemicals are manageable problems; and that deforestation and resource depletion are problems limited mainly to third world countries. There's another book out there: The True State of the Planet (8), edited by Ronald Bailey, that conveys a similar, "the sky is not falling" message to "chicken little" environmentalists. It forecasts a coming age of abundance; says we can wait a while on global warming to get the computer models perfected; claims that famine is a thing of the past for most of the world's people; and so forth.

Honest people of good will and with good intentions can disagree. They can interpret the same data differently, and even reach opposite conclusions, without having to be branded as footdraggers or alarmists. But, how do we reconcile all of this? Where's the truth?

The title of this talk is, "The Journey from There to Here, the Eco-Odyssey of a CEO". Well, "there" is where I was just about a year ago, pushing Intersept through the Envirosense Consortium to make a buck and staying in compliance on all the rest. "Here" is where I am today, with an awakened, sensitized conscience and an awakened, sensitized company; wrestling with what's the truth in all this, and looking for a reconciling statement. I think I have it, or at least the beginnings of it. Here it is:

Whether the earth will run out of oil in 50 years or 650 years may seem like a big contradiction in conclusions reached; but either, in geologic time, is the blink of an eye. Our life span is so short that it's like being in only two or three frames of a movie that has been running a long time and has a long time yet to run. Our time on earth is just so short term that we don't see enough of the movie, can't see the next scene even, much less where it's all headed. But our few frames can have a huge effect on the outcome of the movie. Not to trivialize through analogy, but I remember hearing a NASA scientist say once, talking about Apollo XI, that first man-on-the-moon expedition, that 90% of the time the spacecraft was off course. It was the critically important mid-course corrections that got it there, that determined the outcome.

Our planet is billions of years old and has billions of years to go. Creation goes on. Even the 10,000 years since the agricultural revolution began are a blink of God's eye, barely one second long, if you compress all of geologic time to date into the six days of biblical creation. The industrial revolution started just 1/40th of a second ago on the same time scale.

That 10,000 years is roughly 500 generations. Fifty years of oil is two and a half generations worth; 650 years is 32-1/2 generations worth. So, whether we're talking the last 1/2% of an epoch or the last 6% of an epoch doesn't much matter; time is short. In a blink of God's eyes the whole epoch will be over.

We're part of the continuum of humanity and life in general. We will have lived our brief span and either helped or hurt that continuum and the earth that sustains all life. It's that simple. Which will it be?

How can we help? I believe one person can make a difference, you and I; that people coming together as in organizations like yours and mine can make a big difference; that companies coming together, for example customers and suppliers in recycling efforts, can make a huge difference. If five billion people change their minds (that's Daniel Quinn's mission through Ishmael), and do their daily thing (whatever it is) with the earth's welfare in mind, earth, humanity, and all the continuum of life will gain a new lease on life.

I'm betting that a new paradigm for business will emerge, too: "Doing well by doing good".

Finally, as we used to sing in Sunday School when I was a child, "Brighten the corner where you are, brighten the corner where you are". If we all succeed in doing that, i.e., doing good for Mother Earth in the corner where we live and work, and set the example for others, we will be helping Daniel Quinn in his mission to change five billion minds. Humanity's only hope. Thank you.

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Green Buildings - Achieving Your Design Objectives

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Abstract

Architects and engineers designing environmentally responsive buildings must make decisions throughout the design and construction process that bring their design objectives to fruition. The building industry is a highly fragmented entity that changes slowly. Designers face obstacles such as product shortages, infrastructure limitations, and contractors who are unfamiliar with alternative materials or methods of construction. Overcoming these obstacles requires a systematic approach to selection, specification, construction administration, and commissioning.

Introduction

Designing healthy, environmentally sustainable buildings requires the team efforts of the designers, owners, and contractors throughout the design and construction process. Even after the building is occupied, the building must be maintained well to continue to achieve a healthy indoor environment, and low energy use. Be prepared to take advantage of unexpected opportunities and to make adjustments when your original decisions cannot be achieved.

Design Process

Begin by establishing cost and performance goals for energy and the environment during the Pre-design phase and continue to test and refine these goals throughout design. Figure 1 highlights the steps that Burt Hill takes to integrate these considerations with the traditional design phases.

Look for opportunities that make it easier to achieve the environmental design goals. For example, in the design of the National Public Radio headquarters, an assessment of the building's occupant load and the elevator capacity lead to the elimination of two of the eight existing elevators. This created an opportunity for the recycling chutes to be cost effectively installed (Figure 2). The copier and kitchen areas, two of the highest generators of operational wastes, were co-located with the chutes to encourage effective recycling.

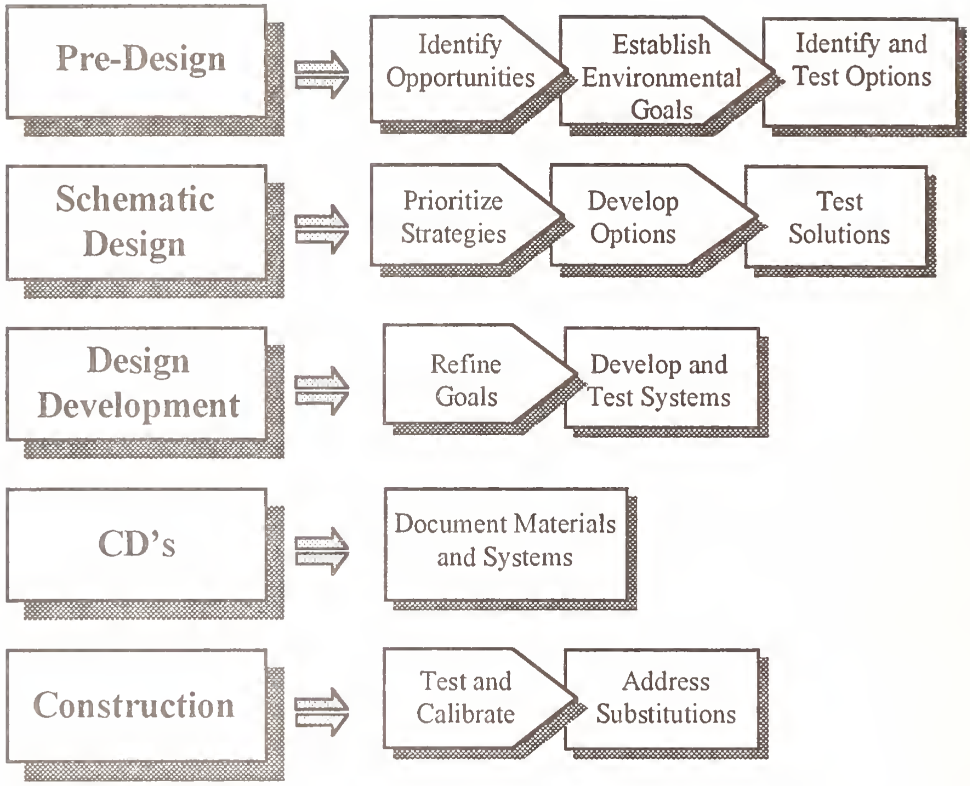

Figure 1: Environmentally Responsive Design Process

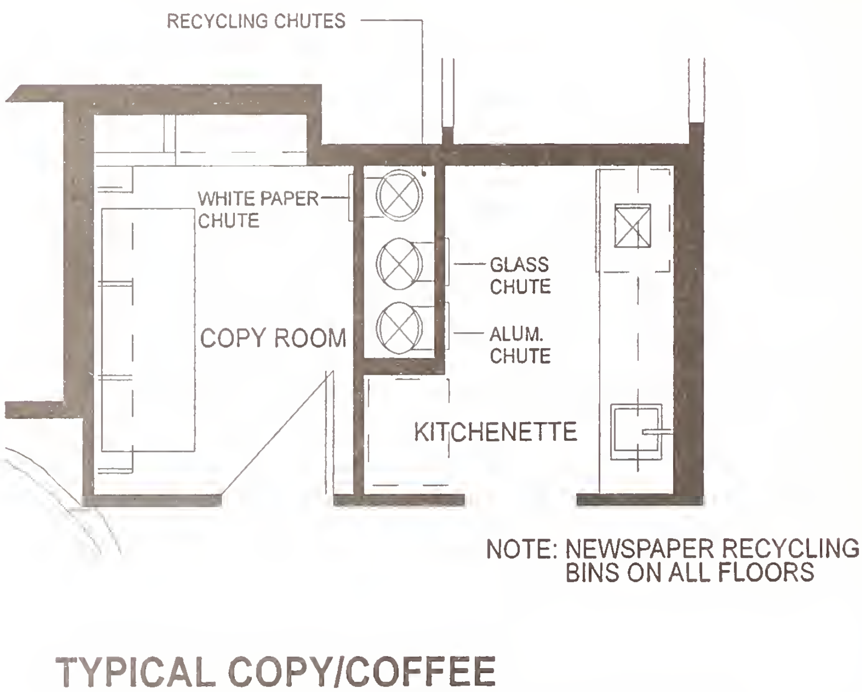

Figure 2: National Public Radio Recycling Center

Environmental Material Selection

When selecting environmental materials, concentrate on the high volume construction materials and those that are in contact with the indoor air. Use a systematic method of selection, with priorities established by the design team and the owner. Burt Hill developed an environmental material comparison approach for the AIA *Environmental Resource Guide*, and uses it to make material choices on projects. It allows the team to decide to place additional emphasis on specific environmental considerations, such as indoor air quality, or the use of materials with high recycled content, if appropriate.

MACRO ENVIRONMENT
- Atmospheric Impacts
- Water Use/Pollution
- Resource Depletion
- Biodiversity/Habitat Loss

ENERGY
- Required for Production/Use of building materials (embodied energy)
- Energy Savings Potential

WASTE
- Recycled Content of Materials
- Recyclability
- Reduction of Construction Waste

HEALTH & WELFARE
- Indoor Air Quality
- Byproduct Toxicity
- Socio-Economic Impacts

Each group of construction materials that will be used in the design is evaluated separately, such as insulation, structural materials, or interior floor finishes. The following example is a comparison for thermal insulation products.

Table 1: Environmental Material Comparison Summary

THERMAL INSULATION	MACRO ENVIRONMENT	ENERGY	WASTE	HEALTH & WELFARE
FIBERGLASS	◆	◆	◆	◆
CELLULOSE	+	+	+	◆
MINERAL SLAG WOOL	◆	◆	+	◆
COTTON	+	+	+	◆
PERLITE	◆	◆	+	◆
EPS	◆	-	◆	+

+ Performs Well   ◆ Performs Moderately   - Performs Poorly

Comparisons can be made at the material level or at the subsystem level (such as exterior wall systems), as appropriate for the project. More detailed assessments are developed as background for each evaluation.

Overcoming Obstacles

Often sustainable building design depends on doing things somewhat differently than in conventional design and construction. Anticipating obstacles is usually the best way of overcoming them. Some typical obstacles are the following:

Material Shortages - Products chosen for specific environmental characteristics, such as synthetic gypsum board (made from flue gas precipitate instead of mined gypsum), may have limited availability in some regions of the country, or may not be easily identifiable by the construction contractor due to labeling limitations. This can adversely affect schedule and may require substitutions. It is useful to identify this as a possible long-lead item during construction negotiations.

Regional Infrastructure Limitations - Recycling of demolition materials or construction waste materials frequently requires an infrastructure in the region that enables contractors to deal directly with companies that recover and reuse these materials. In many cases, the contractor may have difficulty identifying appropriate recycling companies, except for high value construction wastes, such as metal. Some county or municipal governments have developed networks to put construction contractors and recycling companies in touch.

System Integration Issues - Changes in the design of some building systems can affect others in ways that the A/E must anticipate. For example, it is often desirable to eliminate the acoustic insulation lining in HVAC ductwork to avoid potential problems with microbial growth. This may result in somewhat larger duct sizes to lower air velocity noise. In turn, careful planning of the structural, sprinkler, and lighting systems is required to avoid interference conflicts.

Scheduling Issues - Nowhere does the adage "time is money" ring more true than in construction. Paints and other "wet" finishes are usually installed near the end of the construction process. These finishes usually produce volatile organic compounds (VOC's) that outgas and degrade indoor air quality. A common technique for achieving acceptable indoor air quality at initial occupancy is to require a time period for flushing out of these chemicals by using all outside air ventilation. The construction schedule should include sufficient time before the scheduled initial occupancy, for a ten to thirty day flush out period for most products. Sometimes the designer can select finishes that have a shorter decay period until the time when the concentrations of chemicals reach acceptable levels. This may be a particular issue when renovating a portion of an office building floor with a mechanical ventilation system serving multiple tenants. Another issue can arise when the flush out period occurs during peak winter or summer conditions when the HVAC system may not have sufficient capacity to condition 100% outside ventilation air.

Conclusions

When introducing innovations in the building design and construction process, the owner, A/E and builders must work together to set and achieve the design objectives. There will always be trade-offs between cost and performance, especially when using new products and systems. Identify the key design goals and opportunities before beginning the design process, and continue to develop options and test solutions throughout design. The A/E and the builder must work together to anticipate construction scheduling and other obstacles, preventing them from subverting design goals.

EVERYTHING A BUILDING OWNER NEEDS TO KNOW ABOUT GREEN BUILDING HOUSEKEEPING AND MAINTENANCE

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Abstract. Building owners face numerous challenges in operating profitable properties. Among the challenges is the need to maintain both the indoor health and the appearance of the building. These elements affect the health and welfare of the building occupants directly impacting their productivity. Furthermore, these elements impact the perceived quality and marketability of the property. Housekeeping and maintenance in a "Green Building" become one of the keys to maintaining the integrity of the indoor environment, especially after materials of construction and furniture have completed off-gasing, and the HVAC systems have come to equilibrium.

For the indoor environmental quality to be properly addressed, considerations to a number of issues must be made. These considerations begin with the site selection process and design stage. Next is the development of "Green Building" Maintenance Principles which leads to the selection of "Green" maintenance products and ongoing maintenance efforts. Finally is a process for routine surveys and efforts for continual improvement.

Introduction

Building owners certainly have more important issues on their minds when considering a building than the routine custodial, housekeeping and maintenance procedures that will be required. In most instances, the only time these issues become important is when there is a problem. Often times the lack of attention to these details results in the slow decay of a property's value, a general malaise among workers that can't be attributed to any special cause, or just an old, uninspiring indoor environment.

In a worst case scenario, lack of attention to these details results in illnesses to building inhabitants, labels such as Sick Building Syndrome and Building Related Illness, worker injury and compensation problems. It is not the intent of this paper to scare building owners with the horror story that could appear in the local news regarding an outbreak of Legionnaire's Disease or food poisoning at their building. It is the intent to point out that these headline grabbing stories and building labels simply result from poor maintenance and a general complacency regarding these issues.

This paper will not address custodial operations. It is intended to address the issues of which building owners should be aware. Issues that need to be considered right from the very first concepts and site selection. This paper will provide building owners with insights to issues that should be considered from concept to operations, giving clues to what's getting done and what needs to get done to maintain a "Green Building" indoor environment.

Design for Housekeeping and Maintenance

Site Selection

It is many times easier and less expensive to keep soils out of a building, than to remove them once they have entered. Thus, when reviewing the site selection, consider how the existing "neighbors" will affect your building. The three major contaminants of buildings are particles (I.E., soil and dust), gases (I.E., automotive exhausts and industrial emissions) and biocontaminants (I.E., bacteria and fungi from standing water).

Thus, when developing site plans, consider how particles will be tracked into the building. Consider how pedestrian traffic will enter buildings through parking areas, walk-ways, crossing streets, etc. Traffic patterns and entryway systems can be designed to eliminate the particles before they enter the building.

Consider vehicular exhausts and other airborne emissions, especially if constructing in an industrial area. Changing the location of fresh air vents, can make a major impact on the indoor air quality.

Finally, consider the site for the potential of standing water. While particles can cause a general decay in the appearance of the facility and gases can cause discomfort and potential for some health problems, nothing is more devastating to the building occupants than the impact of biopollutants. For example, standing water on neighboring flat roofs can produce the spores that contaminate your building. Standing water on a neighbor's parking lot can seep into your ground level and basement levels causing contamination. Due to the potential seriousness of biocontamination, standing water is a major concern for site selection.

Entrances

Recognize the challenges that entrances present to those who maintain the building. Due to extreme traffic levels and high expectations for the building's appearance, entrances should be designed both to catch the soils before they can be tracked throughout the building, as well as for easy cleaning. This is especially true in a geography that is impacted by severe weather conditions (I.E., ice and snow).

The use of walk-off matting and floor grids can be designed to be an integral part of the entry in such a manner so as not to diminish the aesthetic appearance, and yet to be highly functional in capturing soils. In general, the use of hard to maintain floor coverings, such as soft wood and some carpeting are discouraged for use in high traffic entrances.

The Challenge of Multiple Materials

Beautiful lobbies are designed to enhance the ambiance and make a positive initial statement. However, if the designer gets carried away from an aesthetic point of view, recognize the potential for a maintenance nightmare.

Maintaining the appearance of any high traffic area is in itself a challenge, not to mention the use of multiple materials also requires multiple maintenance methods. For instance, picture an elegant hotel lobby. The floor consists of Italian marble, with deep pile carpeting in front of a registration area, with wooden walkways over a garden area including a water fall and Japanese carp pond, all separated with inlayed decorative metals. While stunning, the use of numerous flooring materials makes responding to even the simplest of maintenance operations, like cleaning up a coffee spill, an enormous challenge. Thus, challenge the designers to create the same ambiance while minimizing the number of materials used.

Custodial Storage Areas

While it is financially critical to make the best use of space, it is also critical to recognize that adequate space for the storage and convenience of maintenance materials is essential. Imagine a home master bathroom with only a small medicine cabinet for storage. The lack of convenient access to essential and frequently used supplies, such as toilet paper and towels, will quickly become an area of user frustration.

In an attempt to maximize usable floor space, designers often reduce the size and number of custodial closets. However, custodial storage areas are essential for the maintenance of a "Green" Building. They must be large enough to store a janitor's cart, shelves to store a minimal amount of cleaning supplies, toilet paper and towels, as well as a sink, and wired for charging electrical equipment.

Chemical Dispensing Equipment

System designers have become very attuned to the concepts of water conservation and energy efficiency when designing buildings. The same concepts exist for the use of automated chemical dispensing equipment. These units are ideal methods for chemical source reduction by often reducing the use of chemicals by as much as 65% when compared to non portion controlled dispensing methods. Furthermore, chemical dispensing equipment allows for the use of super concentrates that reduce the amount of storage space necessary, as well as reducing the overall amount of packaging. Additionally, automated chemical dispensing equipment makes the mixing of concentrated cleaning chemicals much simpler, faster and safer for the maintenance staff.

Mechanical Areas

As with the custodial storage areas, designers trying to maximize usable floor space have a tendency to design mechanical areas, such that they become difficult for even the simplest cleaning to take place. However, mechanical areas can spread particles and biopollutants throughout the whole building. Thus, these areas must be large enough for maintenance workers to clean in and around the mechanical equipment, as well as be able to service the equipment itself.

"Green Building" Maintenance Principles

While Building Owners will not get directly involved with the daily housekeeping and maintenance operations, it is important to recognize that success of any program starts at the top! Due to the significant impact that these operations can have on the building and the fact that these operations tend to be extremely labor intensive, it is important for management to have established a very clear approach to maintenance.

The following is a list of 10 Maintenance Principles:

1. People, Education And Communications. Because labor may constitute as high as 90% of the maintenance budget (and higher in some geographical areas), the focus on people is extremely important. Building owners should encourage the use of total quality management (TQM) of the maintenance operations, including both the maintenance workers and building occupants. Get people involved and make them feel that what they are doing is important. This is the key to success.

2. Clean For Health First And Appearance Second. The real culprits that can harm the indoor environmental quality are the particles, gases and biopollutants that cannot be seen. Thus, the emphasis must be placed on cleaning for health and the elimination of the major pollutants -- not merely keeping the building looking clean.

3. Develop A Holistic Approach To Cleaning. Recognize that cleaning in one area affects the occupants of the building in other areas. This is true in terms of both the off-gasing of cleaning products that can spread pollution throughout the building via the ventilation system, as well as impact traffic flow and noise levels.

4. Planned Maintenance. Well-developed maintenance schedules work best. Schedules should be in writing and available for inspection. Major maintenance operations that may impact building occupants should be scheduled to minimize impacts and disruptions.

5. Accidents Happen! Establish a clear plan of action for responding to accidents and weather related problems. Consider establishing a "Cleaning Hot Line" to establish clear communications between building occupants and custodial workers for rapid response to problems.

6. Minimize Human Exposure To Hazards. Occupants of "Green Buildings" expect to work in a safer environment than those in "traditional" buildings. Thus, ensure that the products used in the building by both in-house maintenance and contractors are the least toxic available.
7. Minimize Residues. Residues from the cleaning and maintenance processes can in themselves become pollutants. Thus, residues should be minimized.
8. Assure Safety At All Times. The safety of the building occupant, worker and the environment is essential. The Department of Labor's Occupational Safety and Health Administration's (OSHA) requires the use of chemical Material Safety Data Sheets (MSDSs). These documents clearly indicate the hazards associated with chemical products. Make sure that these are available and that workers are using the appropriate personal safety equipment. Building occupants should also be informed and protected during building maintenance. This will also include among other things, the use of appropriate signage, such as "wet floors" and "construction areas".
9. Dilution Is NOT The Solution! The use of the HVAC system to minimize or eliminate sources of indoor air pollution is only part of the solution. Sound cleaning procedures to eliminate the sources of pollutants, combined with the appropriate cleaning chemicals are all required to maintain the best indoor environment.
10. Dispose Of Wastes Properly. Not everything can be simply poured down the drain. The building should have a plan for disposing of hazardous wastes and spent products.

Selecting "Green" Maintenance Products

Building owners need to understand only a few basic concepts to assure that the products used in the building will not only perform the chosen tasks cost effectively, but that they are products that will also protect the workers, building occupants and the environment. Unfortunately, the use of environmental claims can often be misleading. It is necessary to consider if product claims are being made regarding the contents, usage or simply the products packaging.

A product that is marketed as "environmentally friendly" may simply mean that it is packaged in a recyclable container. Even so, this product may need to be replaced if the actual product contents are highly toxic or hazardous to the user.

OSHA's Material Safety Data Sheets by law must be kept on file and available for review. These documents are a good source for product information. By periodically reviewing a few MSD Sheets, the Building Owner can demonstrate the commitment to the importance of product usage and can question whether or not the products are the least toxic to perform the task.

A few issues of concern with chemical products for housekeeping and maintenance are:

- Moderate pH. Products with a pH closer to 7 will be safer for the workers. Extremely high pH products, those closer to 14, are extremely caustic and can result in severe burns. Products with an extremely low pH, closer to 1, are acidic and can also cause severe burns.
- Low VOCs. Volatile Organic Compounds are the emissions or the off-gasing from products. Often associated with solvent-based products, VOCs are major components of smog and are responsible for odors and other problems, such as eye, nose and lung irritation.
- Flammable, Corrosive, Reactive Products. The MSD Sheet will indicate if the product in use is considered by OSHA to be flammable, corrosive or reactive. Flammable products can frequently be replaced with water-based products. Corrosives can be replaced with products that are more mild (see comments regarding pH). Reactive products create potential problems for misuse, such as mixing bleach and ammonia, which produces toxic fumes. These products can be replaced with non reactive alternatives.
- Products With Hazardous Constituents. Hazardous ingredients can pose many problems. Problems to workers, building occupants, the waste treatment facility, etc. Often times the cleaning operation can be performed with products that contain no OSHA defined hazardous ingredients.
- Source Reduction. Look for ways to continually reduce both the quantity of chemicals used, as well as the toxicity of the chemicals. Automated chemical dispensing equipment is an excellent method of source reduction.
- Returnable Packaging And Recycling. It is often better for the environment if the manufacturer supplying the chemical products will take back the packaging for reuse. When recycling is the option, ensure that the materials being purchased fit into the building's established recycling program and that actual recycling of the packaging is taking place. Many times products collected for recycling are simply headed for the dump. The use of returnables and recycling have many benefits, including reduced environmental impacts and reduced costs for building waste disposal.

Building Surveys -- What A Building Owner Should Look For

Building owners should periodically inspect their buildings to review housekeeping and maintenance performance. While an annual formal review is recommended, it should also be an issue of constant attention. As management consultant and author Tom Peters points out, "What gets monitored, gets done!"

Particles, Gases And Biocontaminants

As a building owner, always pay attention to your senses -- what is seen, heard and smelled. Make note of the level of particles, gases and biocontaminants in the building. Observe the basic levels of dirt, dust and debris in the building. While floor surfaces are important, perhaps a better indication of the maintenance ability to control particles is the amount of dust on book shelves and other surfaces.

Also, occasionally check the operation and quality of vacuum cleaners. Vacuum cleaners with inexpensive paper bags or no liners at all, simply recirculate pollutants around the building. Simple reviews of this nature demonstrate to your housekeeping and maintenance staff that cleaning is more than just talk.

When problems are encountered, fix them immediately. This is especially important for any signs of water leakage, standing water or stained ceiling panels. Inspect immediately and make the required repairs.

How Soils Enter The Building

Building owners should observe the entry ways to assure that adequate precautions are being made to eliminate soils before they enter into the building. Make sure that entrance systems are being used at all times to catch pollutants before they enter the building, and not just during rain, snow, or other weather conditions.

Maintenance Schedules

Periodically review maintenance schedules to ensure that they are being used and that they are effective. Most successful maintenance schedules have detailed diagrams with square footage, frequency of cleaning and specific activities listed. If your maintenance schedule is simply that one person starts on Monday at one end of the building, and a second person starts at the other end, and they meet on Friday, it is not good enough. A clear plan will not only improve the health and appearance of the building, it will also improve the productivity and morale of the workers.

Storage Areas

Storage areas should be inspected for a number of conditions. Make sure that only clean equipment and chemicals are being stored. This will minimize the spread of pollutants. Check storage areas for flammable, corrosive, combustible and reactive products. Pay attention to all U.S. Department of Transportation (DOT) placards and other warning labels. The observation of the colorful DOT hazard placards should serve as a "red flag" for hazards relating to the products being used and stored in the building. Question both the necessity for the particular product and whether safer alternatives have been investigated.

Occupant Complaints

A file should be kept for occupant complaints and should be periodically reviewed. Complaint records should be reviewed for the type and degree of seriousness, as well as if the overall number seems to be growing. Complaint records should also include the corrective action taken and whether or not the corrective action was appropriate and timely.

Conclusion

If a building smells bad and looks dirty, if soap dispensers in restrooms are consistently empty with no hand towels or toilet paper, your building has a problem. It is bad enough when occupants of the building complain about simple to solve housekeeping issues. But, if they believe that their health is being compromised by chemical emissions or biopollutants, as a building owner, you could have a major problem on your hands.

Although each of these problems may be minor taken by themselves, they can add up to a disaster. Each of these problems is simply due to poor housekeeping and maintenance, and can only be solved by better methods and products. As with solving any critical issue, plan early to address the specific needs of "Green Building" housekeeping and maintenance, establish clear management principles, select the right products and develop ongoing inspections and opportunities for continual improvement. By doing so, you can improve not only the quality of your building, but enhance your bottom line.

MATRIX APPROACHES TO GREEN FACILITY ASSESSMENT

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Abstract. Experience demonstrates that the life-cycle assessment activity for an industrial or commercial facility works most effectively when it is purposely done semi-quantitatively and in modest depth. To facilitate such assessments, we have devised an abridged life-cycle facility assessment matrix. The beginning of a facility's existence - site selection, development, and infrastructure - comprises one life stage, as does the end of facility existence - refurbishment, transfer, and closure. Three aspects dealing with facility active use are also treated: the products made there, the processes used to make them, and facility operations unrelated to products and processes, such as property maintenance and cafeteria services. The matrix scoring system provides a straightforward means of comparing options, and "target plots" are recommended as convenient and visually arresting ways of calling attention to those design and implementation aspects whose modification could most dramatically improve the assessment rating. We demonstrate these tools by performing assessments on common facilities: generic automobile manufacturing plants of the 1950s and 1990s.

LIFE-CYCLE ATTRIBUTES OF A FACILITY

Designating a building as "green" generally involves the assessment of characteristics of the building's design and construction, especially materials selection, its infrastructure (lighting, heating, and so forth), and its eventual conversion to other uses or "deconstruction" and associated materials recycling. All of these aspects of a building's relationship to the wider world are important, but the list is incomplete without the inclusion of the impacts of the activities carried on within the building during its useful life: products that are manufactured within it, the processes that are used in that manufacture, and the ways in which other activities within the building are performed. Clearly a building cannot be truly green if the products and processes within it are not.

Given this perspective, we propose that a life-cycle assessment (LCA) of the environmental responsibility of a facility involves five stages or activities: Stage 1, Site selection, development, and infrastructure; Stage 2a, Principal business activity - products; Stage 2b, Principal business activity - processes; Stage 2c, Facility operations; and Stage 3, Refurbishment/transfer/closure (1). Environmentally responsible facility (ERF) assessment need not and should not be applied only to manufacturing facilities, but rather to any facility engaged in any type of products or services - oil refineries, auto body shops, fast-food restaurants, office buildings, residential structures, and so forth. The assessment will obviously be more complex in some cases than in others, but managers of facilities, no matter what the facility's function, should strive to ERF status.

Stage 1: Site Selection, Development, and Infrastructure

A significant factor in the degree of environmental responsibility of a facility is the site selected and the way in which that site is developed. If the facility is an extractive or materials processing operation (oil refining, ore smelting, and so on), the facility's geographical location will generally be constrained by the need to be proximate to the resource. A manufacturing facility usually requires access to good transportation and a suitable work force, but may be otherwise unconstrained. Service facilities, in many cases, must be located near customers. Office buildings can be located virtually anywhere.

Manufacturing plants have traditionally been in or near urban areas. Such locations often have buildings available and have the advantages of drawing on a geographically concentrated work force and of using existing transportation and utility infrastructures. It may be possible to add new operations to existing facilities, avoiding many of the regulatory difficulties of establishing a wholly new plant site. A promising recent development is the trend toward cooperative agreements between governments and industries for the reuse of these "brownfield" sites (2).

For facilities of any kind built on land previously undeveloped as industrial or commercial sites, ecological impacts on regional biodiversity can be anticipated, as well as added air emissions from new transportation and utility infrastructures. These effects can be minimized with attention to working with existing infrastructures and developing the site with the maximum area left in natural form. Nonetheless, given the current overstock of commercial buildings and facilities in many countries, such "green field" choices are hard to justify from an industrial ecology perspective.

Stage 2a: Principal Business Activity - Products

Tangible products are items manufactured within the facility for sale to customers. Evaluating the environmental attributes of products is a subject that has been vigorously pursued since about 1990. Though parts of the formalism remain contentious, it is agreed that the three main components are an inventory of materials and energy use, an analysis of the environmental impacts of those uses, and recommendations for reducing those impacts (3). The assessment attempts to evaluate impacts over all life stages of the product, on all appropriate temporal and spatial scales. Examples of successful applications of this methodology include studies of automobile front ends (4) and detergent surfactants (5).

Stage 2b: Principal Business Activity - Processes

Processes are the techniques, materials, and equipment used in the manufacture of products. Process assessment has received less attention than product assessment, but should clearly be directed toward the same general goal: the minimization of related environmental impacts on all temporal and spatial scales. Process assessment has been discussed by Allen (6), with particular application to the chemical industry, and in more general terms by Graedel and Allenby (7).

Stage 2c: Environmental Interactions Related to Facility Operations

The impact of any facility on the environment during its active life is heavily weighted by transportation issues. As with many other aspects of industrial ecology, trade-offs are involved. For example, just-in-time delivery of components and modules has been hailed as a cost-effective and efficient boon for manufacturing. Nonetheless, it has been estimated that the largest contribution to the emissions that generate Tokyo smog comes from trucks making just-in-time deliveries. The corporations delivering and those receiving these components and modules bear some degree of responsibility for those emissions. It is sometimes possible to reduce transport demands by improved scheduling and coordination, perhaps in concert with nearby industrial partners or by siting facilities near to principal suppliers. Options also exist for encouraging ride sharing, telecommuting, and other activities that reduce overall emissions from employee vehicles.

Material entering or leaving a facility also offers opportunities for useful action. To the extent that the material is related to products, it is captured by the product LCA assessments. Facilities receive and disperse much nonproduct material, however: food for employee cafeterias, office supplies, restroom supplies, and maintenance items such as lubricants, fertilizer, and road salt, to name just a few. An ERF should have a structured program to evaluate each incoming and outgoing materials stream and to tailor it and its packaging in environmentally-responsible directions. Obviously, the most environmentally preferable products should be chosen in performing each function. For example, purchased paper products should have high recylced content.

Facility energy use requires careful scrutiny as well, as opportunities for improvement are always present. An example is industrial lighting systems, which are responsible for between 5-10% of air pollution emissions overall. Another major contributor is the heating, ventilating, and air-conditioning systems. Office machines and computers in office buildings can use significant amounts of energy. As with many environmentally-related business expenditures, energy costs for specific uses are often lumped in with "overhead" and not precisely known, yet the use of modern technology often has the potential to decrease energy expenditures by 50% or more.

Stage 3: Facility Refurbishment, Transfer, and Closure

Just as environmentally-responsible products are increasingly being designed for "product life extension", so ERFs should be. Buildings and other structures contain substantial amounts of material with significant levels of embodied energy, and the (especially local) environmental disruption involved in the construction of new buildings and their related infrastructure is substantial. Clearly an ERF must be designed to be easily refurbished for new uses, to be transferred to new owners and operators with a minimum of alteration, and, if it must be closed, to permit recovery of materials, fixtures, and other components for reuse or recycling.

MATRIX APPROACHES FOR FACILITIES

A suitable assessment system for environmentally responsible facilities (ERFs) should have the following characteristics: it should lend itself to direct comparisons among rated facilities, be usable and consistent across different assessment teams, encompass all stages of facility life cycles and all relevant environmental concerns, and be simple enough to permit relatively quick and inexpensive assessments to be made. For facility assessment, we recommend the following environmental concerns as amenable to assessment and ameliorative action: impacts of biodiversity, energy use, and generation of solid, liquid, and gaseous residues of various types.

The assessment system that we utilize (7) has as its central feature a 5x5 assessment matrix, the Environmentally Responsible Facility Assessment Matrix, one dimension of which is life-cycle stages and activities and the other of which is environmental concern (Fig. 1). In use, the assessor studies the characteristics of the facility and of the activities that occur within it, and assigns to each element of the matrix an integer rating from 0 (highest impact, a very negative evaluation) to 4 (lowest impact, an exemplary evaluation). In essence, what the assessor is doing is providing a figure of merit to represent the estimated result of the more formal LCA inventory analysis and impact analysis stages. She or he is guided in this task by experience, inspections of actual or planned facility characteristics, appropriate checklists, and other information (Figure 2). The process described here is purposely qualitative and utilitarian, but does provide a numerical end point against which to measure improvement.

Once an evaluation has been made for each matrix element, the overall Environmentally Responsible Facility Rating (R_{ERF}), is computed as the sum of the matrix element values:

$$R_{ERF} = \sum_{i} \sum_{j} M_{i,j} \qquad (1)$$

Since there are 25 matrix elements, a maximum facility rating is 100.

The assignment of a discrete value from zero to four for each matrix element implicitly assumes that the environmental impact implications of each element are equally important. An option for slightly increasingly the complexity of the assessment (but perhaps increasing its utility as well), is to utilize detailed environmental impact information to apply weighting factors to the matrix elements. For example, a certain facility might be thought to generate most of its impacts during as a consequence of the processes used within it and few related to facility operations, so the processes row could be weighted more heavily than before and the facility operations row weighted correspondingly lighter. Similarly, a judgement that global warming constituted more of a risk than did liquid residues might dictate an enhanced weighting of the energy use column and a corresponding decreased weighting of the liquid residue column. To the extent that an appropriate weighting scheme is obvious and non-contentious, its use will provide an improved perspective on the environmental burden of the facility being evaluated.

We have devoted considerable time and effort to analyzing the environmental responsibility of industrial products (8) and processes (7). Our approach in those cases has been similar to the matrix technique described above, but with life stages and environmental concerns appropriate to those activities. In each case we adopt four of the same environmental concerns as used for facilities: energy use, solid residues, liquid residues, and gaseous residues. We replace biodiversity with materials choice, since products and processes are more directly related to materials than to ecosystem impacts.

The life stages are different for products, processes, and facilities. For products, the five life stages that are considered are 1) Premanufacture (those actions taken by suppliers of materials or components that influence the environmental characteristics of the product), 2) Manufacture, 3) Product delivery (packaging, shipping, and installation), 4) Product use, and 5) Recycling or disposal. For processes, the five life stages or activities are 1) Premanufacture (extraction, purification, and transport to the facility the resources used to construct the process), 2) Process implementation (the manufacture and installation of the process equipment), 3) Process operation, 4) Complementary process operation (often the choice of a process implies the use of other processes as well; for example, soldering generally requires a solvent cleaning operation), and 5) Refurbishment, recycling, or disposal of the process equipment itself.

In the facility assessment approach that we advocate, the first step is that products and processes related to the facility are identified and assessed by matrix approaches. The results are then incorporated into the assessment of the facility. Figure 3 shows the way in which the matrices are interrelated; we will illustrate the process in more detail with an example later in this paper.

TYPES OF FACILITIES AND THEIR CHARACTERISTICS

Any assessment approach should ideally be applicable to all varieties of facilities. It is useful, therefore, to briefly review how quite different facilities fall into the framework we have described. In Table 1 we list a number of types of facilities and identify their products and processes.

The first group of facilities are those which operate manufacture products for industrial or commercial customers. These are generally classical "industrial" facilities that have the processing of materials, components, subassemblies, or industrial infrastructure items such as machine tools as their focus. Assessments of this type of facility are reasonably straightforward.

The second group of facilities are those that exist for the purpose of offering tangible products directly to individual consumers. The simplest are those that perform the minimal level of processing: unpacking and shelving. Hardware stores, clothing stores, and small appliance stores are examples of this type. Grocery stores are similar, but typically perform some degree of food processing as well, such as meat cutting and packaging. Some facilities of this type have a more major involvement in processing, as with the agricultural activities of a typical garden center. Perhaps most like the industrial model is the restaurant, where materials (food) are transformed into products (meals) by specific processes (food preparation techniques).

Another type of facility exists for the purpose of offering services to customers. Perhaps the simplest from a conceptual ERF standpoint is a bank, which performs most functions electronically and provides only minimal levels of products: currency, paper confirmation of transactions, and the like. Schools have a somewhat greater diversity of materials, but again the product, education, is largely intangible. A hair salon definitely employs a number of physical and chemical processes, in what we might term maintenance of an item (hair) supplied by the customer. From the perspective of ERF assessment, a beauty salon, an appliance repair shop, and an auto body shop thus play the same role, maintenance of a customer-supplied item.

ASSESSING GENERIC AUTOMOBILE MANUFACTURING PLANTS

As a demonstration of the operation of the tools described above, we perform environmentally-responsible facility assessments on facilities reasonably familiar to all, at least in concept: generic automobile manufacturing plants of the 1950s and 1990s. Some of the relevant characteristics of the facilities, their products, and their processes, are given in Table 2.

In overview, the 1950s vehicle was substantially heavier, was less fuel efficient, prone to greater dissipation of working fluids and exhaust gas pollutants, and had components, such as tires, that were less durable. The processes used for manufacture in the 1950s were much more energy-intensive than is the modern practice, and some problematic processes, such as metal cleaning with chlorofluorocarbons and painting with high-volatility organics, have been modified or eliminated. The internal recycling of materials, once hardly considered, now occurs much more extensively.

While it is fairly straightforward to picture and describe typical automobiles of different eras, and the processes by which they were made, there has historically been a wide variation in the types of manufacturing sites and their development. Thus, for pedagogical purposes, we describe two extremes that will serve to illustrate assessment ranking differences. The site chosen to represent the 1950s is an existing industrial site (a "brownfield"), with already available commercial power, road networks, and other municipal services. The building itself is of brick, with steel framing and supports as required. Bus and trolley transportation are readily available to many of the employees. Heating is provided by coal burning, and air conditioning has not yet become routinely available. Incandescent lighting is abundant. Much of the land is grassed, mowed, and regularly treated with fertilizers and pesticides. The building itself is "purpose-built", as the British say; it is not designed with the idea of ever using it for any purpose other than automobile manufacture.

In contrast, the site typical of the 1990s is built on a site new to commercial development: a "greenfield". Instead of modification or reconstruction of an existing building, natural land areas are developed, together with the necessary infrastructure of roads, power lines, water and sewer services, and so forth. The structure is concrete, with extensive use of composite materials. Because the site is not near public transportation, private automobiles are by employees to go to and from work. Heating is provided by natural gas, and modern air conditioning units with the potentially-ozone-depleting refrigerant CFC-12 is used. In keeping with more enlightened modern practice, a substantial fraction of the grounds is maintained in a natural condition.

We begin the assessment by treating the first life stage, that of facility site selection, development, and installation of infrastructure, guided by our matrix element checklists (1). The ratings, and brief descriptions of the principal reasons for them, are as follows.

Ratings: Site Selection, Development, and Infrastructure

Element Designation	Element Value and Explanation
1950s plant: Biodiversity (1,1)	2 (Brownfield site, but has biotic impacts)
Energy use (1,2)	3 (Few modifications to energy infrastructure)
Solid residue (1,3)	2 (Significant solid residues in site prep)
Liq. residue (1,4)	3 (Modest liquid residues in site prep)
Gas residue (1,5)	3 (Modest gaseous residues in site prep)
1990s plant: Biodiversity (1,1)	1 (Greenfield site, large biotic impacts)
Energy use (1,2)	0 (Complete new energy infrastructure)
Solid residue (1,3)	1 (Abundant solid residues in site prep)
Liq. residue (1,4)	3 (Modest liquid residues in site prep)
Gas residue (1,5)	3 (Modest gaseous residues in site prep)

The second stage of facility assessment is that of the environmental responsibility of the products made within the facility. In an earlier publication (8), we performed a detailed matrix assessment on generic automobiles of the 1950s and 1990s, and will not repeat that assessment here. In overview, however, we evaluated the impacts of the products at each life stage for the five environmental concerns mentioned previously. For incorporation into the facilities assessment, the integer ratings for each of these impacts were summed over all five life stages, and then divided by five to put the rating on the same scale with the other facilities stages considered in this paper. For example, the five materials choice ratings for the 1950s automobile were 2, 0, 3, 1, and 3. Their sum is 9, and the sum divided by 5 is 1.8, which is entered into Figure 4.

Ratings: Principal Business Activity - Products

Element Designation	Element Value
1950s plant: Matls. choice (2,1)	1.8 (CFC cleaning, virgin materials)
Energy use (2,2)	1.4 (Fossil fuel energy use is very large)
Solid residue (2,3)	2.2 (A number of components are difficult to recycle)
Liq. residue (2,4)	2.6 (Fluid leakage during operation)
Gas residue (2,5)	1.2 (No exhaust gas scrubbing; high emissions)
1990s plant: Matls. choice (2,1)	2.6 (Petroleum is a resource in short supply)
Energy use (2,2)	2.4 (Energy use during manufacture is fairly high)
Solid residue (2,3)	2.8 (Modest residues of tires and obsolete parts)
Liq. residue (2,4)	3.2 (Some liquid residues from cleaning and painting)
Gas residue (2,5)	2.6 (CO_2, lead [sometimes] emissions)

The third activity stage is processes, the techniques for product manufacture. The basic automotive manufacturing process has changed little over the years but much has been done to improve its environmental responsibility. One potentially high-impact area is the paint shop, where various chemical are used to preclean the parts and where volatile organic emissions are generated during the painting process. There is now greater emphasis on treatment and recovery of waste water from the paint shop and the switch from low-solids to high-solids paint has done much to reduce the amount of material emitted. With respect to material fabrication there is currently better utilization of material (partially due to better analytical techniques for designing component parts) and a greater emphasis on reusing scraps and trimmings from the various fabrication processes. Finally, the productivity of the entire manufacturing process has been improved, substantially less energy and time being required to produce each automobile.

As with the product assessment, we will not describe here the entire process rating, but give the results and some of the principal reasons for the ratings.

Ratings: Principal Business Activity - Processes

Element Designation	Element Value and Explanation
1950s plant: Materials choice (3,1)	2.0 (CFCs used for metal cleaning)
Energy use (3,2)	1.8 (Substantial process energy use)
Solid residues (3,3)	1.2 (No solid residue recycling)
Liquid residues (3,4)	2.0 (Liquid residues from metal processing)
Gaseous residues3,5)	2.0 (No control of paint shop emissions)
1990s plant: Materials choice (3,1)	2.6 (Few materials recoverable at facility demise)
Energy use (3,2)	2.0 (High energy needs for process removal)
Solid residues (3,3)	2.2 (Substantial solid residues at facility demise)
Liquid residues (3,4)	2.8 (Moderate liquid residues)
Gaseous residues3,5)	3.0 (Few gaseous emissions concerns)

The fourth life stage, facility operations, has been described above; it encompasses any activities not directly related to products or processes. The ratings for the two generic facilities are as follows:

Ratings: Facility Operations

Element Designation	Element Value and Explanation
1950s plant: Biodiversity (4,1)	0 (Pesticide use, all areas altered)
Energy use (4,2)	1 (Profligate energy use in facility operations)
Solid residue (4,3)	0 (No attempt to minimize solid residues)
Liq. residue (4,4)	0 (Extensive liquid discharges)
Gas residue (4,5)	2 (Moderate VOC emissions)
1990s plant: Biodiversity (4,1)	3 (Natural areas, no pesticides)
Energy use (4,2)	3 (Modest energy use in operations)
Solid residue (4,3)	3 (Extensive waste minimization and recycling)
Liq. residue (4,4)	3 (Extensive liquid residue treatment)
Gas residue (4,5)	3 (Efficient gaseous residue controls)

The final life stage assessment is for facility refurbishment, transfer or closure. In the case of the 1950s facility, the design employed no consideration of reuse, so total demolition constitutes the only reasonable option available. For the 1990s facility, designed so that interior walls may be modified, wires, cables, and pipes added readily and inexpensively, and building services updated in modular fashion, reuse is a reasonable expectation.

Ratings: Refurbishment/Transfer/Closure

Element Designation	Element Value and Explanation
1950s plant: Biodiversity (5,1)	1 (Major ecological impacts upon demolition)
Energy use (5,2)	1 (Major energy use in demolition and clearing)
Solid residue (5,3)	1 (Little reuse of materials possible)
Liq. residue (5,4)	2 (Significant liquid residues when demolished)
Gas residue (5,5)	2 (Significant gaseous residues when demolished)
1990s plant: Biodiversity (5,1)	3 (Little ecological impact when reused)
Energy use (5,2)	3 (Modest energy use when reused)
Solid residue (5,3)	3 (Extensive reuse - low demolition probability)
Liq. residue (5,4)	3 (Minor liquid residues when reused)
Gas residue (5,5)	3 (Minor gaseous residues when reused)

The completed matrices for the generic 1950s and 1990s automobile manufacturing plants are illustrated in Fig. 4. Examine first the values for the 1950s facility so far as life stages are concerned. The column at the far right of the table shows good environmental stewardship during site development, and moderate environmental stewardship regarding product design, manufacture, and use. The ratings for facility closure are poor, and those for facility operations are abysmal. On the basis of the environmental concerns, shown by the column additions, the summed ratings for biodiversity and solid residues are particularly low. The overall rating of 41.2 is far below what might be desired.

In contrast, the overall rating for the 1990s facility is 64.2, much better than that of the earlier facility but still leaving plenty of room for improvement. The life stage that is particularly egregious is that of site selection and preparation. Energy use and solid residue generation receive the lowest ratings of the environmental concerns.

The matrix displays provide a useful overall assessment of a design, but a more succinct display of DFE design attributes is provided by the "target plots" shown in Fig. 5. To construct the plots, the value of each element of the matrix is plotted at a specific angle. (For a 25-element matrix, the angle spacing is $360/25 = 14.4^{\circ}$.) A good product or process shows up as a series of dots bunched in the center, as would occur on a rifle target in which each shot was aimed accurately. The plot makes it easy to single out points far removed from the bulls-eye and to mark their topics out for special attention. Furthermore, the comparison of target plots for alternative designs of the same product permits quick comparisons of environmental responsibility. The product and process design teams can then select among design options, and can consult the checklists and protocols for information on improving individual matrix element ratings.

DISCUSSION

A corporation designing its products with the DFE philosophy in mind should apply a similar approach to its processes and facilities. The system that we have presented in this paper can be readily adapted to these cases. Considerations include the environmental impacts arising from construction and eventual disposal, the materials used during facility operation, and the consequences of associated activities. With a few modifications, the approach can be used not only for traditional manufacturing facilities, but also for those covering the full spectrum of human activities, as indicated in Table 1.

Unlike classical highly-quantitative life cycle assessment, facility life-cycle assessment as presented here is less quantifiable and less thorough. It is also inestimably more practical and utilitarian; it is far better to conduct a number of abridged LCAs (ALCAs) by these or similar techniques than to conduct one or two comprehensive LCAs. A survey in the modest depth that we advocate, performed by an objective professional, will succeed in identifying perhaps eighty percent of the useful DFE actions that could be taken in connection with corporate facility activities, while consuming sufficiently small levels of time and money that the assessment has a good chance of being carried out and its recommendations of being implemented.

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Table 1. Product and Process Characteristics of Typical Commercial and Industrial Facilities

Facility	Product	Process
	Facilities Offering Products to Commercial Customers	
Ore smelter	Metal ingots	Smelting and refining of ores
Chemical works	Chemicals	Processing of chemical feedstocks
Appliance mfr.	Washing machines	Assemble products from components
Recycler	Components, materials	Disassemble and reprocess obsolete goods
	Facilities Offering Products to Individual Consumers	
Hardware store	Tools, supplies	Unpacking, shelving
Grocery store	Food, related items	Unpacking, shelving, food processing
Garden center	Plants, related items	Agricultural activities
Restaurant	Meals	Food preparation
	Facilities Offering Services to Customers	
Bank	Financial services	Electronic transactions
School	Education	Classroom instruction
Post office	Mail handling	Mail sorting and delivery
Hair salon	Hair maintenance	Chemical and physical treatments

Table 2. Salient Characteristics of Products, Processes, and Facilities for Generic Automobile Manufacturing Plants of the 1950s and 1990s

Characteristic	ca. 1950s	ca. 1990s
PRODUCT: The Automobile		
Material content (kg):		
Plastics	0	101
Aluminum	0	68
Metals	1583	1047
Rubber	85	61
Fluids	96	81
Other	137	76
Total Weight: (kg)	1901	1434
Fuel Efficiency (miles/gallon)	15	27
Exhaust Catalyst	No	Yes
Air Conditioning	CFC-12	CFC-134a
PROCESS: Auto Manufacture		
Energy use	Enormous	Substantial
Painting	Organic high-volatile	Aqueous low-volatile
Recycling	Some	Extensive
Process hardware		
Welding	Frequent	Ubiquitous
Conveyer belts	Numerous	Numerous
Complementary processes		
Metal cleaning	CFCs	Aqueous detergents
FACILITY: Auto Manufacturing Plant		
Site	"Brownfield"	"Greenfield"
Worker transport	Bus, trolly	Private auto
Heating	Coal	Natural gas
Lighting	Incandescent	High-eff. fluorescent
A/C Fluid	None	CFC-12
Grounds	Fertilizer, pesticides	Natural areas
Building mtls.	Brick, steel	Concrete, composites
Recycling	No	Yes
Closure	Demolition	Reuse-adaptable

Figure 1. The Environmentally-Responsible Facility Matrix					
	Environmental concern				
Facility activity	Ecological impacts	Energy use	Solid residues	Liquid residues	Gaseous residues
Site Selection, development, and infrastructure	1,1	1,2	1,3	1,4	1,5
Principal business activity-Products	2,1	2,2	2,3	2,4	2,5
Principal business activity-Processes	3,1	3,2	3,3	3,4	3,5
Facility operations	4,1	4,2	4,3	4,4	4,5
Refurbishment, transfer, and closure	5,1	5,2	5,3	5,4	5,5

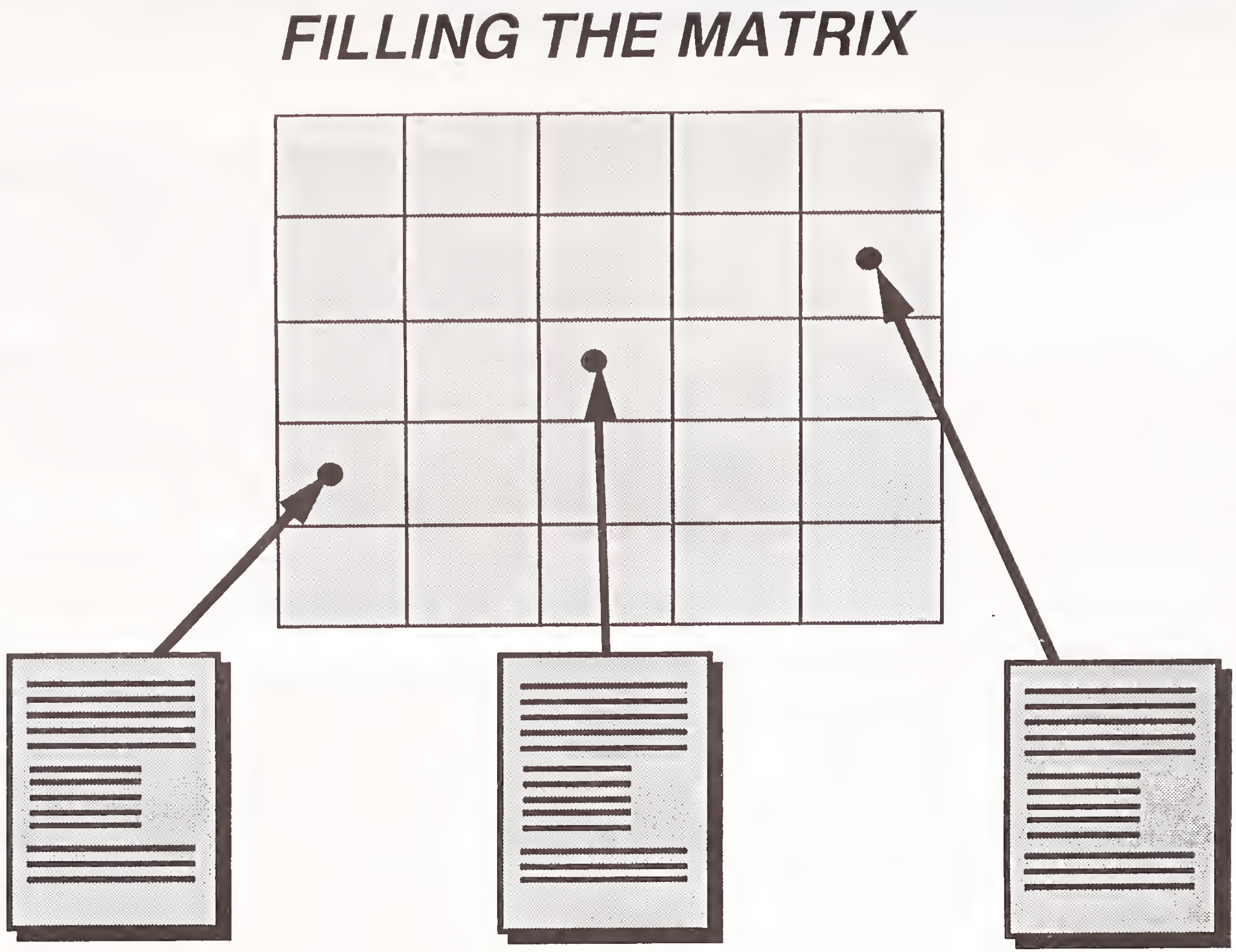

Figure 2. The relationship between the matrix and the underlying checklists and protocols that drive its evaluation.

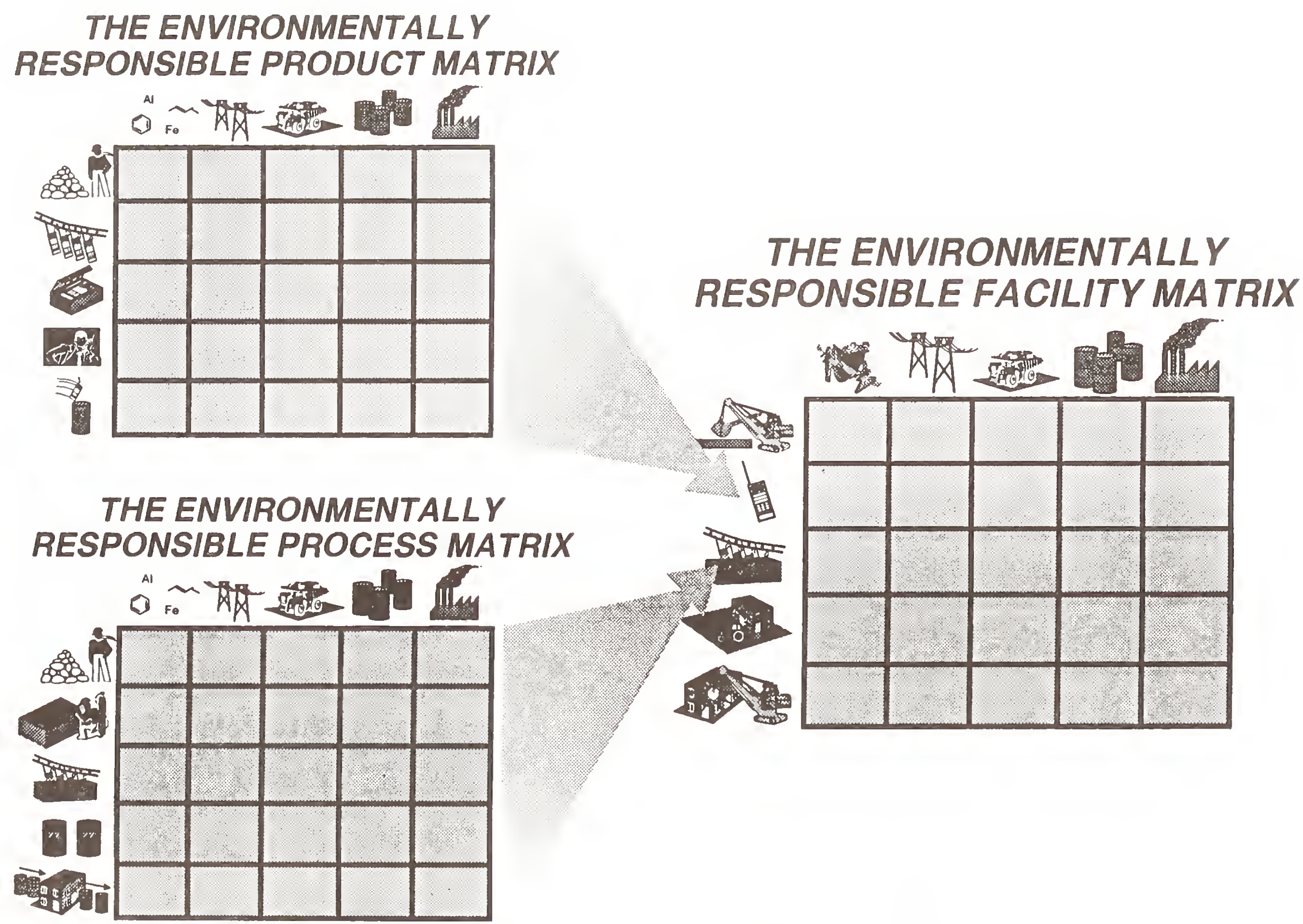

Figure 3. A schematic diagram of the interrelationships among product, process, and facility matrices.

Figure 4. Environmentally Responsible Product Assessments for Generic 1950s and 1990s Automobile Manufacturing Plants*						
	Environmental Concern					
Life Stage	Biodiversity, Materials‡	Energy Use	Solid Residues	Liquid Residues	Gaseous Residues	Total
Site Selection, development, infrastructure	2.0 1.0	3.0 0.0	2.0 1.0	3.0 3.0	3.0 3.0	13.0/20 8.0/20
Principal business activity - Products	1.8 2.6	1.4 2.4	2.2 2.8	2.6 3.2	1.2 2.6	9.2/20 13.6/20
Principal business activity - Processes	2.0 2.6	1.8 2.0	1.2 2.2	2.0 2.8	2.0 3.0	9.0/20 12.6/20
Facility operations	0.0 3.0	1.0 3.0	0.0 3.0	0.0 3.0	2.0 3.0	3.0/20 15.0/20
Refurbishment, transfer, and closure	1.0 3.0	1.0 3.0	1.0 3.0	2.0 3.0	2.0 3.0	7.0/20 15.0/20
Total	6.8/20 12.2/20	8.2/20 10.4/20	6.4/20 12.0/20	9.6/20 15.0/20	10.2/20 14.6/20	41.2/100 64.2/100

* Upper numbers refer to the 1950s facility, lower numbers to the 1990s facility.

‡ The ratings in this column for life stages one, four, and five refer to impacts on biodiversity, for stages two and three on choice of materials.

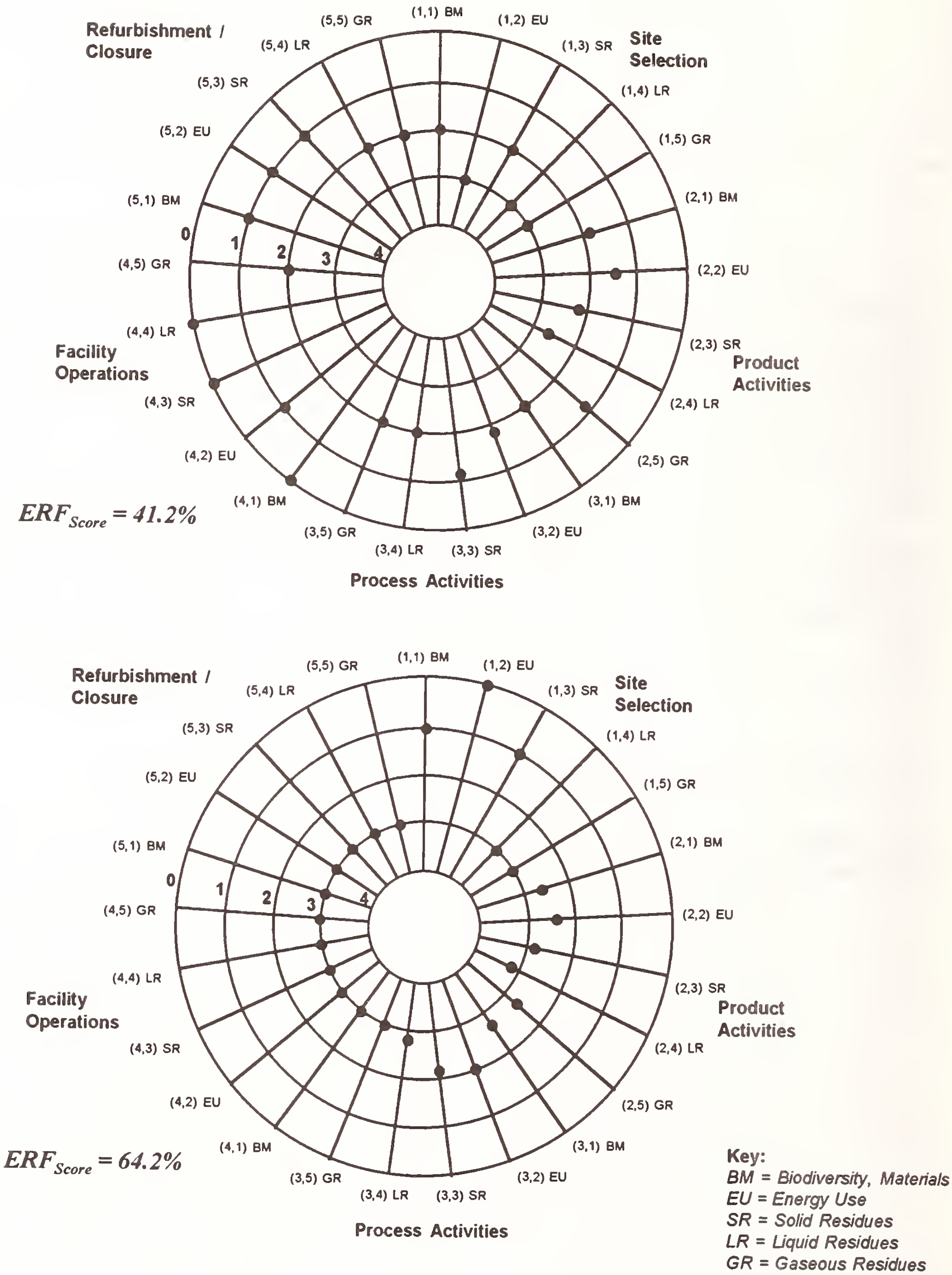

Figure 5: Comparative target plots for the display of the environmental impacts of generic automobiles of the 1950s (top) and of the 1990s (Bottom).

PALE GREEN HOUSE IN THE HOT DRY VALLEY

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Abstract. As an element in the Pacific Gas and Electric Company's Advanced Customer Technology Test (ACT^2) program, a 1672 ft^2 single family home was designed and built in the Sacramento Valley to test the hypothesis that an integrated package of energy-efficiency measures could be installed at costs competitive with new energy supply from the electric utility perspective. Based on a detailed program plan which allowed use of "mature market" cost estimates for immature technologies, the design team selected a package of 29 energy-efficiency measures (EEM's) using a rigorous performance/cost methodology. Featuring many innovative shell improvements and a comprehensive set of measures to eliminate cooling load, the home was completed and occupied in December, 1993. Detailed monitoring data confirm successful operation of the integrated energy package. While energy efficiency was the major program emphasis, many of the selected EEM's may become key "green" building elements based on their materials origin and use characteristics.

Introduction

The California energy-efficiency movement which flourished in the early 1990's was spurred by support from electric utilities as an element of the "Demand-Side Management" strategy to delay needs for new generating capacity. That movement is now seriously threatened by deregulation of the electric utility industry. Concurrently, the green building movement is gathering momentum with strong support from environmental interest groups. While most energy-efficiency technologies are "green" in that they preserve fossil fuel resources and counter both global warming and ozone depletion, many such measures are also "green" from the construction materials standpoint. This paper examines a project designed for optimal, cost-effective energy efficiency for its potential as a "green building" in addition to its performance results.

The Pacific Gas & Electric Company's Advanced Customer Technology Test (ACT^2) program was designed to test the hypothesis that an integrated package of energy-efficiency measures could be installed at costs competitive with new energy supply from the electric utility perspective. Using a detailed program plan which allowed use of "mature market" cost estimates for immature technologies, design/build teams were selected for new and retrofit commercial and residential buildings. The teams developed and implemented packages of energy-efficiency measures (EEM's) for specific project applications. The ACT^2 program plan specified commissioning work during and after construction to verify proper installation of all EEM's, followed by detailed monitoring for the first two years' occupancy to evaluate performance of all EEM's. The residential design/build team, which included Davis Energy Group and Ridge

Builders Group of Davis, CA, completed construction of the first ACT^2 residential project in December, 1993.

Design

Project design has been described in a detailed report (1) and has been summarized by Amory Lovins, a key participant on the ACT^2 Steering Committee (2). This paper provides a brief design summary to introduce features with green building value. Since summers in the Sacramento Valley are hot and dry, with high temperatures frequently above 100 °F, the design team placed significant emphasis on reducing cooling loads.

Beginning with a 1656 ft^2 one story design used by Ridge Builders Group for nine previous homes in the selected subdivision, the ACT^2 project data team developed a base case computer model which reasonably matched average energy consumption for the recently-completed homes. By complying with California's strict 1993 Title-24 standards, the base case home was already quite energy-efficient.

The design team used the base case model in conjunction with a rigorous performance/cost methodology to evaluate the economics of more than 80 potential energy efficiency measures. In a first "schematic design" step, the team reviewed form and glazing characteristics of the base case house, and suggested improvements which reduced perimeter length and total glazing area. These changes were projected to reduce life cycle construction, maintenance, and replacement costs by more than $3000 and total annual space conditioning energy use by more than 80%. Most of the predicted life cycle cost savings resulted from reducing the areas of exterior walls and windows. The new floor plan grew to 1672 ft^2 despite its reduced perimeter length.

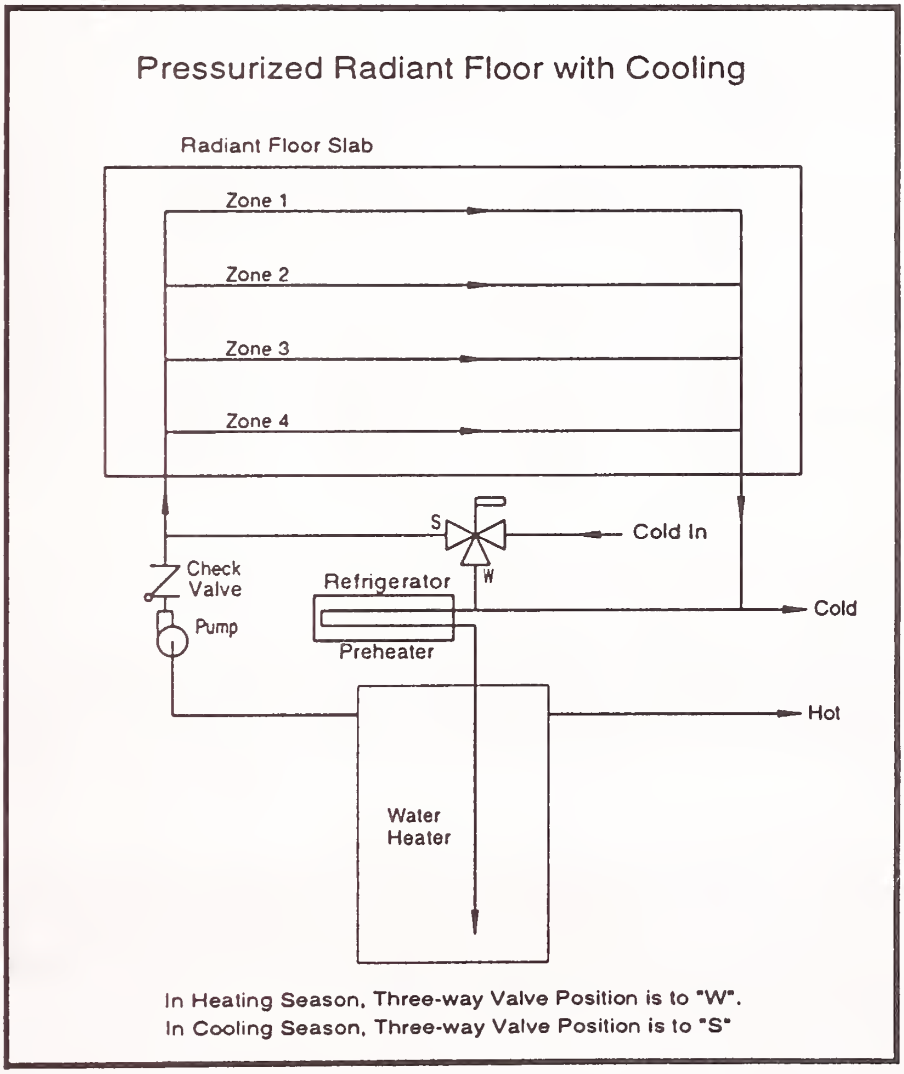
After schematic design, the team first screened candidate EEM's by:

1) analyzing the performance and economics of each applied to the base case,
2) ranking the results, and
3) eliminating EEM's with unfavorable economics.

Next, the team built three alternate packages using a "sequential analysis" process which added EEM's in order of decreasing cost-effectiveness until the last measure just passed the economic test. Analyses were based on DOE-2 simulations in conjunction with a life cycle cost methodology using utility marginal cost projections. The three packages were distinguished by HVAC system approach. The selected package was developed using a "sub-packaging" strategy to eliminate mechanical cooling. When an initial packaging effort determined that a small cooling load remained after all cost-effective EEM's had been identified, the team found that a group of measures which failed the test individually could be combined to eliminate the remaining cooling load, and would be cost-effective as a group when credited with the remaining cooling system budget.

The ACT2 program goal was to cost-effectively reduce overall energy consumption. The design team attempted to analyze EEM's in approximate relationship to projected base case energy use.

All three packages included features to reduce energy use for water heating, lighting, and appliances in addition to space conditioning. In the final package, space and water heating are provided by a single high efficiency water heater. The system delivers ideal heating comfort by pumping hot water through pressurized tubing in the floor slab, on thermostat demand. In summer, all cold inlet water passes through the floor tubing to provide passive floor cooling. A combined refrigerator-water heater was also specified and installed to help control space conditioning loads. In summer, refrigerator heat output preheats domestic water rather than discharging its heat to the kitchen. In winter, refrigerator heat output assists with both space and water heating. Several recent articles provide additional information on the combined refrigerator-water heater (3, 4). Fig. 1 shows the water system flow schematic.



Slab edge insulation, R-27 walls, attic radiant barrier, a light-colored roof, high performance windows, partial double ceiling drywall, partial tile floors, insulated doors, a whole house fan, and ceiling fans were also selected and installed as cost-effective measures to reduce heating and cooling loads. Several features were selected to reduce hot water energy use including low flow fixtures, parallel piping, added tank insulation, and anti-convection valves. Attractive electronic-ballast fluorescent lighting fixtures were specified, and major appliances were also carefully selected for energy-efficiency.

Table 1 summarizes projected overall savings percentages by function, ignoring "plug loads" which could not be reasonably projected during the design phase because no buyer had yet been identified. More than 78% savings were projected for these major energy use categories.

Table 1: Projected Energy Use and Savings by Function

	Base Case Use		Package Use		Package
	kW	therms	kW	therms	Savings
Heating	115	275	61	57	78 %
Cooling	796	0	64	0	92 %
Water Heatin	0	189	20	38	79 %
Lighting	1737	0	568	0	67 %
Refrigerator	1314	0	279	0	79 %
Total	3962	464	992	95	78 %

Construction, Commissioning, and Operation

After completion of design, market conditions dictated that the home be "pre-sold" prior to construction. Potential buyers were screened in search of a family with relatively full-time occupancy expectations. The home was ultimately purchased by working parents with two teenage daughters.

During construction, EEM installations were carefully monitored by the design/build team both to ensure proper performance and to consider potential improvements for future projects. All active systems were "commissioned" by testing and reporting to verify expected temperatures, flow rates, and energy outputs, in accordance with a detailed commissioning plan. An operations manual was prepared and reviewed in detail with the buyers.

During the first year of operation, the owners received considerable guidance from the design build team and ACT^2 project manager in accordance with the program plan. In the second year, beginning December, 1994, the owners were instructed to operate the home and systems without guidance from the ACT^2 project team. Other than minor problems with several appliances, home operation has proceeded smoothly and the buyers have been pleased with their high comfort level and low energy bills. A performance report will be prepared by the ACT2 data analysis contractor after completion of the two year monitoring period.

Green Building Features

The Davis ACT2 house is "pale green" in its major emphasis on energy efficiency rather than natural or recycled building materials, and, in the absence of funding or an approved rating procedure, no attempt has been made to test or measure its overall "tint." However, potential overlaps
between green and energy-efficency design strategies are apparent in key design features of the house. Features bearing further discussion in this regard include the *integrated design strategy, tile floors, engineered wall framing, and the combined-refrigerator water heater*.

The *integrated design strategy* which packaged a group of compatible and sometimes synergistic EEM's sought to cost-effectively minimize total energy use, without considering materials origin or imbedded energy. Major strategic results included significant reductions in required building materials (framing lumber, insulation, drywall, and stucco for exterior walls; glass and framing for windows), and elimination of standard mechanical components (furnace, associated flue and gas piping; split system air conditioner, refrigerant, refrigerant piping, plenums, ductwork, and registers). In addition, a stainless steel water heater with 20 year expected life was substituted for the 11 year conventional unit. Since many of the eliminated mechanical components use highly manufactured metal parts and require periodic replacement, the integrated design strategy appears also to be a green design strategy.

However, the strategy also added components which beg further review before completing a bottom line green tally. The total weight of polybutylene floor tubing may exceed the weight of conventional plastic flex ducts, hence requiring more synthetic materials for heat distribution compared to the base case. Whole house and ceiling fans partially counter the materials savings from cooling system elimination (but should not ever require full replacement as the air conditioning system undoubtedly would). Attic radiant barrier uses an added component, aluminum foil, to reduce cooling loads. Double drywall ceilings partly counter mass savings from minimizing exterior wall materials.

The integrated design strategy relies in part on more efficient refrigeration and lighting systems to reduce cooling loads and capacity. But fluorescent lighting fixtures use more materials and more complex manufacturing than incandescent bulbs with comparable light output; high efficiency refrigerators use more insulation and/or larger metal heat exchangers. Cooling load was also slightly reduced by using parallel hot water piping which substitutes small direct tubing lines to all fixtures, instead of the traditional "trunk and branch" system. Parallel piping saves energy by reducing the volume of hot water left to cool off in the piping system after each draw. This approach typically uses more copper, but minimizes fittings, solder and labor compared to the tree layout. For most of these components, the bottom line color regarding origin and imbedded energy is not immediately clear. However, it seems likely that their overall environmental rating, considering both origin and energy savings, is favorable.

Substitution of *tile floors* for carpet also counters the wasteful (and land-filling) replacement pattern which the green movement seeks to correct. In the base case design, tile was typically placed in the entry and kitchen areas. The added cost for tile vs. carpet was not found to be cost-effective on its own, but became an element in the previously-discussed cooling elimination package. With other features, the added floor slab mass made accessible by the thermally-conductive tile surface eliminated the small remaining cooling system. Additional tile could only be justified in the "living zone" (living and sleeping zones were separately analyzed in the simulations) because sleeping zone cooling loads had been eliminated by other cost-effective measures. Thus, tile floors were substituted for carpet in the dining and family rooms.

In the life cycle cost studies, the base case carpet was assumed to need replacement at 15 year intervals vs. the lifetime durability assumption for tile. Greater durability, lower anticipated energy use for floor cleaning (extended vacuum cleaner life?), lower imbedded energy, and absence of outgassing give tile a clear advantage over carpet on the green building scale.

The *engineered wall framing* (EWF) system introduced in the Davis ACT2 house and subsequently used in two other advanced research houses responded to the design team's observation that in conventionally-framed California homes with 8' ceilings, wood framing occupies approximately 35% of the opaque exterior wall area. (Title-24 energy calculations erroneously assume that only 15% of the wall area is occupied by wood.) This discrepancy reduces wall thermal resistance by almost 25% vs. title-24 assumptions because wood is more conductive than insulation. Just as significantly, it suggests that more wood is used than is structurally necessary. In fact, structural requirements are often met by redundancy rather than engineering. Many extra wall studs are used, and full 4 x 12 headers are used even over narrow door and window openings.

To counter excessive wood use and improve wall thermal performance, the design team developed a framing concept (see Fig. 2) which places R-27 rigid isocyanurate insulation between studs on 24" centers, and creates a 1-1/4" airspace (which doubles as a wiring cavity) between the foil-faced insulation panels and the interior drywall. In this configuration, the insulation panels improve structural strength by resisting stud buckling and wall racking, and also provide support for the exterior stucco surface. An oriented-strand lumber was selected as the basic EWF structural material. Produced in large flat sheets and then sawed to the desired framing dimension, this material is produced from new growth "weed" tree species such as poplar and aspen. The production process minimizes waste, and the product has significant advantages in dimensional stability over conventional sawed lumber.

The final EWF configuration uses 1-1/4" wide by 4-3/4" deep studs on 24" centers to provide necessary wall strength with minimal thermal conduction through wood framing. In addition, door and window framing details have been carefully engineered for adequate strength with minimal thermal transfer. Total wood volume needed for EWF construction is approximately half that needed for conventional framing. While now roughly twice the cost per board foot of conventional lumber, costs of oriented-strand lumber are expected to fall substantially as production capabilities increase. Thus, savings in both materials and labor should generate a significant future framing cost advantage for EWF.

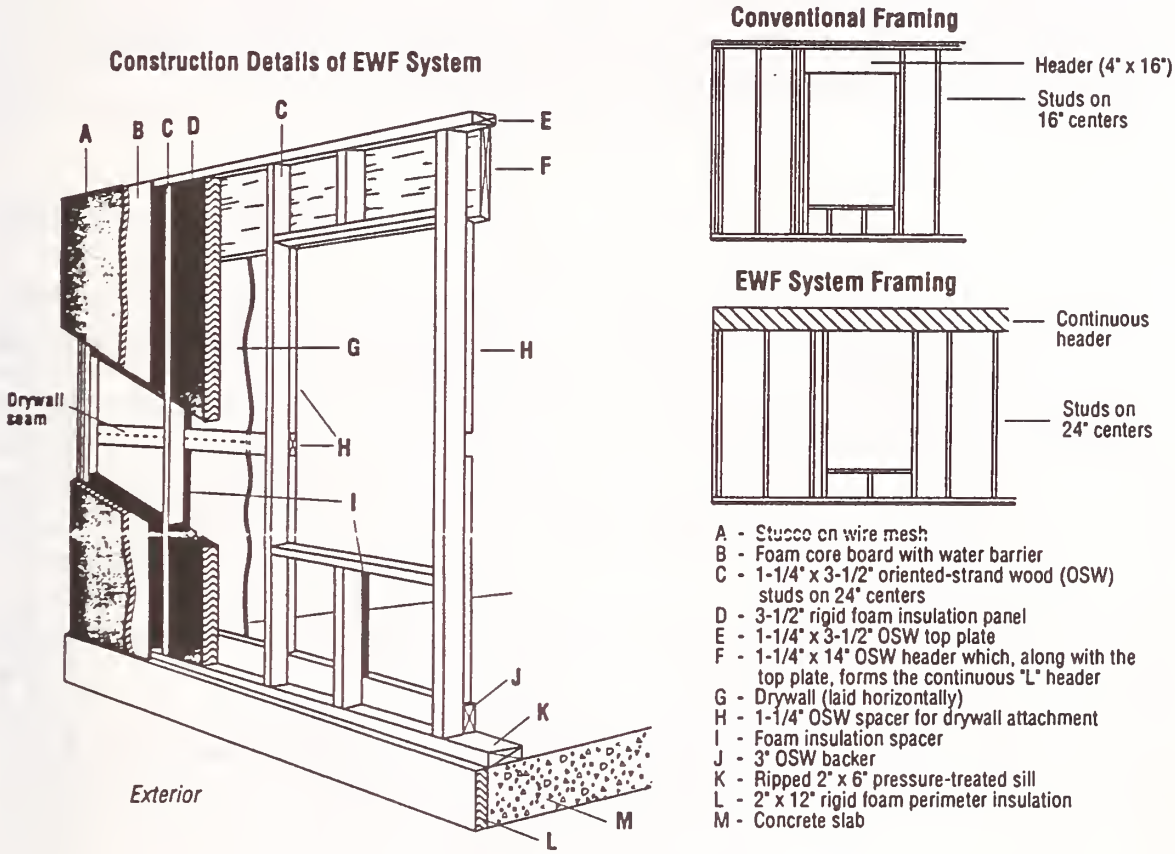


Figure 2: Engineered Wall Framing Isometric

From the environmental standpoint, the EWF system is not all green. Countering its major pluses (energy efficiency and improved wood processing) are several negatives associated with the rigid insulation. The rigid isocyanurate panels were selected because they provide the highest available thermal resistance per inch thickness, with the additional benefit of a reflective foil surface which adds approximately R2 value to the 1-1/4" thick airspace. Negative #1 is the aluminum foil surface sheets. While aluminum requires bauxite (whose mining is often destructive to rain forests) and high input energy, this negative can be countered by use of recycled aluminum. Negative #2 is the blowing agent in the foam production. The manufacturer currently uses an HCFC, having converted from a CFC blowing agent several years ago. They are researching other alternatives, but no change is yet scheduled.

The *combined refrigerator-water heater* (CREWH) saves energy by using waste heat from refrigeration to heat domestic water. This concept has been previously described in the ACT[2] Davis House final report and in several previously-referenced publications. The technology offers substantial source energy savings when used as a stand-alone water heater. CREWH economic value derives partially from displacing gas consumption and partly from reducing cooling loads; the unit basically converts the refrigerator from a space heater to a space cooler. The unit also saves floor space by stacking the hot water storage tank either above or below the refrigerator food storage compartments. Fig. 3 shows one CREWH configuration.

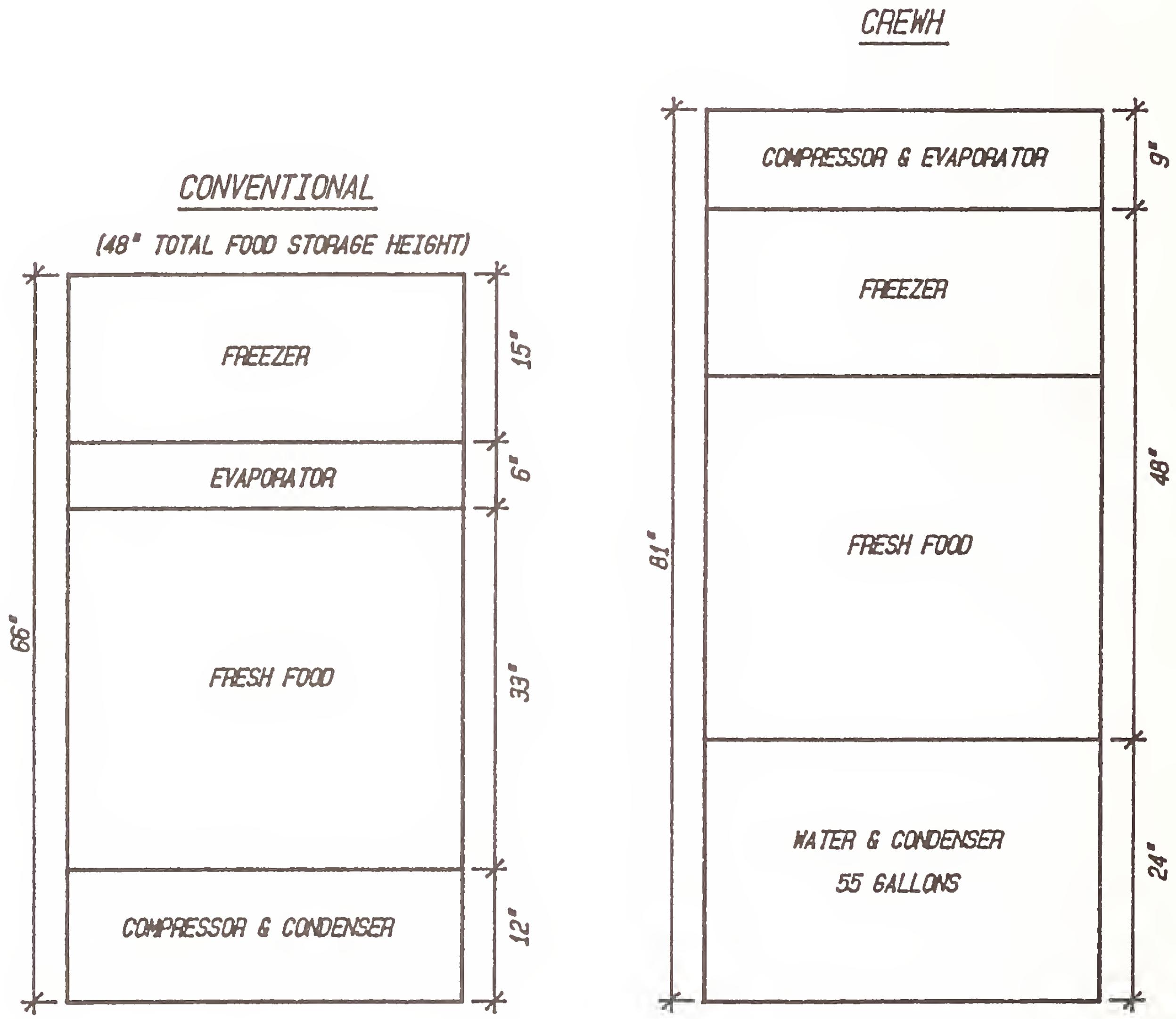


Fig. 3: Sample CREWH Configuration

Potential value of the CREWH as a green technology results from elimination of on-site natural gas combustion for water heating, reducing site and source energy use, possible reduction of cooling system size and energy consumption, and reduction of overall product weight and volume by combining the two functions. There are no obvious CREWH negatives as a green technology. However, CREWH economics appear marginal when the unit is used as a pre-heater, as was necessary in conjunction with the high efficiency gas combined space and water heating selected for the Davis ACT^2 house. The preferred CREWH market may be in apartments, where use with heat pumps (air- or ground-source) would facilitate efficient all-electric design in many locations.

Conclusions

Assuming that the relative environmental value of a building will ultimately be characterized on a color scale with a deep green target, the Davis ACT^2 house would likely be colored pale green, because the major design focus was cost-effective energy-efficiency rather than perfect selection of environmentally benign systems and materials. A review of key energy-efficiency features of the house suggests the synergy of the energy-efficiency and green building movements. Selected features of the project, including the integrated design strategy, tile floors, engineered wall framing, and refrigerator water heater, all appear to offer environmental benefits over and above their energy-efficiency characteristics.

The qualitative "green review" offered in this paper suggests the following conclusions:

1) Systems which cost-effectively reduce energy use typically offer additional green benefits.
2) Careful siting and preliminary design can reduce total building materials requirements.
3) "Passive" design features typically substitute benign materials for highly manufactured, shorter life components.
4) Elimination and combination of hardware systems can help reverse our trend toward disposable goods.
5) Establishing overall green ratings for components and/or buildings will be a complex task..

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ReCRAFT 90: Materials Choices and Performance

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Abstract

ReCRAFT 90, a demonstration project of the Center for Resourceful Building Technology, utilizes more than forty recycled and resource efficient building products. The 2,400 square foot custom home provides a tangible illustration that building with less dimensional lumber and using recycled materials can produce a functional, yet aesthetically appealing structure.

Building and Resources

In building, the siting, design and materials selection all affect the monetary and environmental cost and the performance of the structure. For those attempting to build an "environmentally friendly" house, the selection of appropriate materials requires consideration of availability, embodied energy, resource use, toxicity, durability, maintenance, recycled content and potential for reuse or recyclability. The environmentally appropriate building material choice is rarely clear or obvious. Oftentimes, a builder's familiarity with a certain material or a client's aesthetic preference influences the selection away from what might be more environmentally sound alternatives.

Today, the supply of good quality dimensional lumber is diminishing while costs are increasing. Limits to primary resource extraction are being realized not only for wood, but for other resources as well. From glass, metals and plastics, paper and wood waste, municipal recycling coordinators are beginning to recognize that recycling and/or remanufacturing may be a viable method for managing secondary resources. The building products industry is responding to these resource management challenges with products that are either not dependent upon large diameter, mature timber, or that incorporate recycled materials into the manufacturing process.

ReCRAFT 90

ReCRAFT 90 is an upper median cost, 2400 square foot single family home built in Missoula, Montana, using more than forty resource efficient building materials in a design after the Frank Lloyd Wright tradition. The house sits on a southwest facing slope with the rear of the house partially bermed into the hillside to reduce heat loss. The project was designed to demonstrate alternative technologies and materials that use natural resources more efficiently, with minimal job-site waste. Construction on the project was completed in Spring of 1992, and since then it has served as a national example of resource efficient building.

Material and Design Selection Criteria

The process of locating, selecting and obtaining resource efficient systems and materials for this demonstration project was not a simple one. We tried to find locally manufactured products to minimize the energy used in transporting them to the job site, but unfortunately there are very few secondary manufacturing facilities in or near Montana.

In selecting building materials or systems for ReCRAFT 90, we were concerned primarily with:

- resource and energy efficiency_
- water conservation
- indoor air quality

We also considered the energy and materials required for any future maintenance, demolition and replacement of products.

For example, we considered wood siding for ReCRAFT 90. Wood siding does not take much energy to process, and can be produced locally, but it does require a great deal of labor and materials for maintenance over its estimated 40 year life in order to remain in functional condition. It requires a medium or large diameter tree to be sawn with acceptable dimensional stability. The protective finishes that it would need, such as paint or stain, also require energy for their production. Finally, wood is flammable and a liability in the forest/grasslands of the semi-arid west.

As an alternative we considered, and finally decided upon, a wood fiber-cement composite siding. This product takes more energy (roughly twice that of wood siding) to manufacture and transport, but is relatively maintenance free, extremely durable and is not dependent on large diameter timber as a fiber source.

Meanwhile, in the design of the home we chose dimensions that fully utilized standard sized components, and attempted to design in as much space efficiency as possible to reduce the overall size of the structure. We did aim for a house that met conventional criteria in terms of size and salability. All installations were fully to code.

Foundation

For the concrete foundation and floor slabs we used a fly ash additive to replace 20 percent of the cement. Due to the increased strength (3,400 p.s.i. rather than 3,000 p.s.i.) achieved by incorporating fly ash in the concrete mix, we were able to use 6" thick foundation walls rather than the standard 8". While in this instance the price was 65 percent more for the fly ash mix ($85/ton rather than $50/ton for standard concrete) the overall foundation cost was only about 12 percent more due to the reduced volume of concrete used.

We laid down an ethafoam "Sill Seal" product to provide infiltration control on the top of the foundation walls. On top of this we set a borate-treated 2 x 6 wood mudsill. The waterproofing system used on the outside of the concrete walls is a spray asphalt tar (not an emulsion, but a true tar product) . For insulation, we used a high density compressed fiberglass sheathing called Baseclad (Fiberglass Canada). This material, which was applied to the exterior of the eight foot high concrete walls all the way down to the footing, provides a 3.4 per inch R-value and a capillary break against ground moisture as well as water coming from the surface. Reusable steel forms were used for all the foundation work. Due to the location of the house, radon mitigation measures were an important component of the design. Before pouring the floor slab, we spread 4 inches of 3/4" washed gravel and laid down 3 inches of high density fiberglass duct board ("Baseclad") which allows radon gas to enter into it, where it can be collected for venting through the heat recovery ventilator exhaust.

Basement framing

In the daylight basement area below the main floor, some stud wall framing was required to flush up to the top of the concrete foundation walls. We employed advanced framing techniques, placing studs on 24" centers instead of 16" centers, and using single top plates. These techniques allowed us to use about 17 percent less wood for those walls. We purchased finger-jointed lumber (Champion International) for most of the remaining interior wall studs and plates in the house, instead of #1 or #2 sawn lumber. We were extremely pleased with the quality of the finger-jointed lumber, since all studs were straight and clean and easy to work with. It was nice not to have to deal with the checking, bowing and twisting common in regular dimensional sawn lumber. The finger jointed lumber had to be specially ordered, but did not take long to get.

Floor joists

The 11 $^{7}/_{8}$" I-joists we used (supplied by Trus-Joist MacMillan) were engineered so well that every one was exactly the same, with no knots, dings, checks or twists. With lengths available up to 65', we were able to custom order the exact lengths needed, and as a result, job-site waste was significantly reduced. Most of the I-Joists used were 22' long, which is typically longer than standard lumber joists. The flanges on these joists are $^{3}/_{4}$" x 2" wide, and provided ample surface area for sufficient gluing and nailing of our subfloor. The use of long I-joists works well with an open floor plan, reducing the need for mid-span bearing walls required for dimensional lumber joists. At the time of construction of ReCRAFT 90 (Fall of 1991), I-joists were not readily available at the lumber yard so we had to allow more lead time to get them delivered to the job site from the regional distributor in Montana. This situation has since changed, and today I-joists are readily available in most areas of the country.

The rim joist at the floor joist line of the perimeter walls consists of $^{1}/_{2}$" Oriented Strand Board (OSB). We stapled the floor joists to the rim joist to prevent any racking or twisting, and set "squash blocks" of 1 x 3 pine to bear the load of the perimeter walls at the end of the I-joist. The OSB rim joist provided a good infiltration control between the double top plate and the bottom plate of the wall above.

For the subfloor on the main level we used a product called Comply® made by the Oregon Strand Board company in Brownsville, Oregon. Consisting of three veneers of hemlock and fir sandwiched around two layers of sawdust to create a 5-ply structural subfloor board, Comply is very dense and strong. Comply contains 6-8 percent phenol-based glue, as opposed to two percent glue in OSB. This extra glue gives the product greater stiffness, allowing greater spacing between joists, and thereby conserving wood. The Comply was easy to nail and showed very little sagging between the two-foot-on-center floor joists. While OSB swells at all joints and edges when it gets wet, Comply did not. As is true with many of the products used in ReCRAFT 90, we had to special order Comply, but it has since become a regularly- stocked item at the lumber yard. The cost of Comply was the same as OSB.

To minimize floor squeaks, we used construction adhesive to bond the subfloor tightly to the joists. The two brands used, (Schulte and Hilti) have very low levels of volatile organic compounds and did not have any noticeable odor during application

Nails, and in fact almost all metal products used in the home building industry, are manufactured in electric furnaces which use recycled metals as their primary feed stock.

First level walls

After the subfloor was down, we glued and nailed a 2 x 6 finger-jointed bottom plate $^1/_2$" from the edge of the subfloor to receive $5^1/_2$" structural insulated foam core wall panels (AFM Corporation). With a $1^1/_2$" deep foam recess, the panels were set over the top of the plate with the $^1/_2$" sheathing aligning flush with the edge of the subfloor. To avoid any reaction with the styrofoam, a water-based adhesive/sealer was used here. There was a distinct advantage to using finger-jointed lumber for the bottom plates, in that nearly all of them were perfectly straight. Because of the small degree of tolerance in the panels, the bottom plate has to be straight when tipping the panels in place.

The stress-skin panels did provide the advantage and convenience of a whole wall assembly with sheathing, structural support, and insulation (R-26) as one integral system. Because of their continuous "skins" the panels also reduced potential air leaks through the walls. However, due to the hybrid nature of the house design, there were very few areas where we could just tip up a panel and move ahead briskly with the next one. We got some large sizes - including a few 16' and 18' long, 8' tall panels - and the sloping site did not leave room for a crane to operate. It took six men to carry the large panels. We found ourselves framing in headers for wide window openings over 4' 6", then going to stress skin panels, framing in laminated veneer lumber headers, then going to stress skin panels, etc. This back and forth motion definitely slowed us down and the process took longer than a standard framing operation would have taken.

The width consistency of the panels was actually pretty good, and we were able to slide the finger-jointed connecting plates in the sides, tops and bottoms of the panels with no problem. The finger-jointed 2 x 6 top plate sat flush with the top of the OSB on the panels, and once the top plate was in place all the way around the house, it effectively strengthened and straightened all the perimeter walls. Where two top plates met at a corner, we butted them flush and used a metal gang nailer plate that held the panels together. On outside and inside corners, the panels had to be glued and screwed together with very long (8") screws. We considered using 12" pole barn spikes, but their $^3/_8$" diameter could have split the 2" x 6" within, so we used the 8" screws on 12" centers. It was not easy to screw through the $6^1/_2$" panels to get a good purchase of wood on the other side to hold the corner together.

A more simplified house design with long wall sections and 4' 6" or smaller window headers could be more easily built with stress-skin panels. In addition, panels and joint designs have evolved since the time we built ReCRAFT, so that different assemblies are possible that may be more suited to a wide range of designs.

Window headers

For the window spans with more load carrying requirements than a foam panel header could carry, we used a laminated veneer lumber (LVL) product called Microllam made by Trus Joist MacMillan. Microllams, like other LVL's, have a fairly high amount of glue, and therefore are a little more difficult to cut and harder on saw blades than conventional lumber. We used carbide blades, which maintained sharpness reasonably well, but caused excessive splintering of the veneers. Every piece of Microllam that we handled was uniform and straight, and we had very little waste.

Upper level walls

While the shell of the upper level was also built with stress-skin panels, all the interior walls were framed on 2' centers with finger-jointed 2 x 4's. On the upper level we had less total window area to cut out and we kept the bedroom egress windows within a 4' width, so the framing went more quickly.

As it would have been difficult to run a plumbing vent through the perimeter walls without sacrificing the panels' structural and thermal integrity, we ran the stack vents through the interior walls rather than the outside perimeter walls. While it required a little poking and pulling to run the wiring through the wall panels, it was not nearly as difficult as we thought it would be. We figure we saved time by not having to drill through wall studs.

Honeycomb panels

The floor system on the upper level consists of structural panels (Bellcomb Technologies) with $^1/_2$" OSB skins and a honeycomb core of phenolic-resin-saturated kraft paper. The panels we used are $6^1/_2$" thick overall. The panels are built to specifications off of blueprints, although minor changes can be made on-site, and we did do some field cutting. The panels were very well machined and fit together extremely well. Installation was quick and straightforward. The splines were fastened with glue and $^1/_4$" drywall screws from both top and bottom as recommended by Bellcomb. We used a glue by Hilti that contained few VOCs.

Tests show that these panels maintain 70% strength when wet, and nearly regain their full strength when they dry. Just prior to having final sheathing and drying-in of the roof, we did get some rain, but it appeared to not affect the panels that were already installed. When tested by the carpenters, the honeycomb floor showed minimum deflection and excellent strength and support for a 17 to 20 foot span. The tile setter who later installed the cement board substrate for the bathroom tile commented that the consistency and strength of the honeycomb floor system helped in maintaining the integrity of his tile job.

The manufacturer sent us some $1^1/_4$" x $5^1/_2$" OSB studs to serve as structural rim joist material. These splines were installed to support the load of the roof trusses and stress-skin wall panels of the upper level of the house bearing directly on the edge of the honeycomb around the perimeter walls. We screwed and glued finger-jointed 2 x 3s on the underside of the honeycomb to provide a shallow plenum for wiring and the hot water heating pipes. We furred the mud sill up $4^1/_2$" around the perimeter to accommodate the furring down of the honeycombs, and still maintain a $96^1/_2$" overall room height.

Roof framing

The roof structure consists of a truss roof and a vault. The roof trusses were engineered to use small dimensional lumber. We originally wanted to use machine-stress-rated (MSR) finger-jointed lumber, but the truss engineer would not sign off on it because he had no calculation provisions on his computer for finger-jointed lumber to be used in tension. Instead, we used #1 and #2 structural 2 x 4s and 2 x 3s. Placed on 2' centers throughout, the trusses are hipped on the corners and sheathed with $^{5}/_{8}$" oriented strand board sheathing. This system holds up a fiber/cement slate roof that weighs about 400 pounds per square, plus a 60 pound snow load.

The vaulted ceiling is framed with 14" deep I-joists connected to 14" x 5" "Parallam" (Truss-Joist MacMillan) hip rafters. The alternative was to build up four 22" deep parallel cords with 2 x 4s and bolt them together to carry the same load that the Parallam carried. Parallam has a high glue content and it was hard on the blades in our 14" non-carbide beam saw. They also produced lots of slivers. The I-joists are connected to the hip rafters with unique 45° metal hangers. The I-joists were light and easy to work with off high scaffolding.

Exterior trim

The subfascia around the perimeter of the roof consists of finger-jointed 2 x 6s, over which we applied PrimeTrim™, made by Georgia-Pacific from wood waste and phenol glue. Fascia materials cut and tooled easily and nailed up well, although we did experience minor swelling around some of the nail penetrations.

For soffits we used a $^{7}/_{16}$" thick oriented strand board product made by Louisiana Pacific. This came in 4' x 8' sheets which we cut on site. We had intended to use a fiber-reinforced cement soffit material from FibreCem, but we experienced some breakage just stacking the boards at our shop and decided that they would be too brittle to install overhead on-site.

This was not a problem with the slates and siding. For the frieze band and other horizontal trim boards we used a 1 x 8 or 1 x 6 strand board product made by Louisiana Pacific. It cut, worked, and nailed up the same as conventional wood.

Insulation

For below-grade insulation we furred in the interior of the concrete basement walls on 2' centers with finger-jointed 2 x 4's and blew in cellulose with a water-based adhesive to achieve R-19. The exterior wall insulation was provided by the foam core of the structural stress-skin panels, giving us an insulation value of R-26.

With a substantial snow load in western Montana, we wanted to keep our insulation weight as light as possible in the vaulted ceiling with its long span. For this reason, we chose fiberglass and used the blown-in-blanket system (BIBS) instead of batts to give us optimum R-value per inch. To dissipate heat and moisture in the roof cavity, we installed ventilation baffles in the I-joists and blew in the fiberglass to a depth of 13", giving us a one inch vent area within the space provided by the 14" deep I-joists space.

We blew in 18" of cellulose insulation into the entire attic to achieve R-49. Even with the density of cellulose, we still had plenty of load carrying capability in the $^{1}/_{2}$" Gypsonite that we used on the two foot centers in the ceiling.

Follow-up air tightening reduced the ACH (air changes per hour) to 1.2 at 50 pascals.

Interior wall finishing

The $^1/_2$" Gypsonite wall board that we used was both liked and disliked by the sheetrockers. The first thing they noticed was the weight. With a higher density from the 18 percent newsprint content, the Gypsonite weighed 77 pounds for a 4' x 8' x $^1/_2$" sheet as opposed to 44 pounds for conventional drywall. Today this product is marketed as Louisiana Pacific Fiberbond. The composite wall board nailed up fine, but cutting, scoring and breaking was not as easy. This was due to the higher density and different consistency of the newsprint in the board. We did not have the special carbide bit required for routing out outlet boxes, so these also took a little bit longer to knock out than it would have taken with regular drywall. Also, the special caulking that came with the Gypsonite had a grit in it which created problems for the tapers. For one wall of each of the children's rooms we also used a recycled content tag board. This product (Homasote) is made entirely from recycled paper compressed into a $^1/_2$ inch thick board and faced with burlap (a coarse jute fabric). The paints, penetrating oils, varnishes, and sealers in the house are all water based or contain extremely low if any amounts of volatile organic compounds (VOCs), which are believed to cause various respiratory problems.

Windows and doors

The windows for ReCRAFT 90 are custom made casements consisting of high-performance glass from Southwall Technologies within fiberglass frames from Owens Corning. The frames have standard nailing fins on them and were installed the same as any other window.

The cost of the fiberglass, foam-insulated front door was about 15 percent more than a conventional solid wood door, but we feel that the durability and improved R-value over a wood door make this premium well worth the investment. For the passages from the garage into the laundry room and to the exterior, we used insulated steel doors made from 100 percent recycled metal. They are extremely durable and have an insulated core of expanded polystyrene foam to increase their thermal efficiency. The only other exterior door in the house is a swinging french door double glazed with low-E glass with a triple point locking system to reduce air infiltration.

The interior doors are all raised-panel doors with panels made by the Masonite Corporation from wood waste and phenol-formaldehyde glue.

Roofing slates

We chose a manmade slate for the roofing surface. Produced by the FibreCem Corporation, these embossed slates are pressed out of finely ground sand, cellulose fiber and cement, and have an acrylic coating on the surface. At 380-400 pounds per square, they are lighter than traditional slates and much lighter than tile (at 900-1000 lbs./sq.), and we did not have to increase the size of dimensional lumber or decrease our spacing of trusses to carry both live and dead load. The price of the slates was similar to high quality cedar shingles that, despite being highly flammable and coming from old growth cedar forests, are still used in many areas of the country. The fiber-cement slates are non-flammable, long lasting and came with a sixty-year warranty, although they have proven not durable in freeze-thaw climates. Nails had to be set manually for each slate, as the use of a pneumatic nail gun or stapler would likely have led to some breakage. This increased the installation labor by four or five times. We flashed the two valleys on the roof with copper (another commonly recycled metal) , fastening it with copper nails to reduce the potential for galvanic degredation. For the drip edge flashing, we used aluminum. With a butylene membrane "ice and water shield" back-up for water proofing at the roof valleys , we were able to avoid any metal contact.

Siding

The lap siding used on ReCRAFT 90 is also a fiber-cement product made of cellulose fiber, finely ground sand and cement. It is more durable than wood, holds paint well and comes with a fifty-year warranty. To cut the fiber-reinforced cement siding, we used a diamond saw blade on our cross-cut saw, which worked fine but created a fine dust requiring the use of a respirator by the person cutting the material. We also had to clean the armature and brushes of the saw with compressed air every day to reduce wear. We "blind nailed" the boards into the $^1/_2$" OSB "skin" of the stress-skin panel every 12" on center with a ring shank nail. We stapled 30-pound felt paper underneath the lap siding to provide a good moisture and weather barrier between the siding and the stress skin exterior wall panels. Such felt paper is made from waste paper fiber and asphalt.

The final part of the exterior to finish was the wall surface just above grade outside the daylight basement. We attached chicken wire to 30 pound felt paper stapled to the $^1/_2$" OSB sheeting and hand troweled a cement-based tinted stucco over the chicken wire. The longevity of stucco is very good in this climate.

Floor finishes

We used a variety of recycled and reused materials for the flooring in the house. Tile was chosen for the flooring material in the bathrooms. We found three different brands of tiles made with some recycled content. "Prominence" by GTE and Stoneware Tile Co. both contain recycled glass. Another brand is manufactured using waste aggregate recovered from the mining of feldspar (Summitville Tiles). We used durable traditional linoleum in the front entry closet and in the kitchen, made from a blend of wood dust or wood flour with pine resin talc, and a flax backing. The carpeting that we used in the living room area and on the stairs to the upper level is made from clippings of wool blended with acrylic. The other carpet we used is made of recycled soft drink bottles. We also used two different varieties of recycled carpet pad. One is manufactured from hemp and jute fiber recycled from textiles and the other is manufactured from shredded tire rubber.

Cabinets, countertops, stairway and trim

For cabinet boxes, countertops and vanities we used a high density particle board, called Medex, made from sawdust and wood chips bound together with a formaldehyde-free glue. Medex comes either unfinished or finished with a surface of vinyl or melamine on one or both sides. To save on material, we went with a frameless cabinet style, and for countertop surfaces we chose standard Formica, which consists of 80 percent paper, and is very thin yet durable.

Instead of burying thousands of board feet of lumber in the structure of the house, we chose to use wood where we could appreciate it, as interior trim and finish. Most of the wood used for trim in the house was remilled from lumber salvaged from other remodeling jobs. (Note: Much of the wood discarded during remodeling of old structures is clear-grained lumber harvested in the early 1900's. The growth rings are close together and the wood is oftentimes almost knotless.) We chose not to paint any of it to let the natural color and grain show. After a few months, this reused wood developed a beautiful golden patina. For wide areas such as column facings and middle posts, we cut and end-matched the grain from smaller pieces.

Energy and Water Conservation

While we have focused primarily on the resource efficiency and embodied energy of the building materials in ReCRAFT 90, energy efficiency in use is equally important, and ReCRAFT 90 is designed with a low "design heat loss." At 2400 square feet, ReCRAFT 90 has a design heat loss of less than 33,000 BTUs/hr at minus 22°F design temperature. This is about $^2/_3$ less than a conventional house of the same size. This particular location in Montana has 8,130 heating degree days.

To reduce energy needs for heating and cooling, we built a very tight and extremely well insulated shell, reducing conductive and infiltration heat losses. ReCRAFT 90 is designed to expose little surface area to the environment in order to keep the exterior surface at or near ground temperature rather than exposing it to radically fluctuating air temperatures. Since this is a single family detached home built on a hillside, our best method for reducing the exposed surface area was by berming the house into the hillside. Overall, air leakage was reduced by employing airtight construction practices, sealing all cracks and gaps, installing windows and doors with low tested infiltration rates, and limiting penetrations in the building envelope such as for fans and electrical fixtures. Therefore, the house has a very low natural air exchange rate.

To further reduce heat losses, we limited the amount of dimensional lumber in the exterior wall (to minimize conductive losses) by using the foam-core panels. We used high levels of insulation above and below grade (R-26 above grade walls; R-21 below grade walls; R-10 slab; R-50 roof), and built the garage on the north side of the house to temper north winter winds.

With a low design heat loss, ReCRAFT 90's heating system does not have to be as large as a less-efficient similar sized home. We installed a condensing sealed combustion gas-fired boiler (Weil-McLain "Gold") with an efficiency rating of 90-95 percent. This 105,000 BTU/hr boiler provides both hot water and space heating through two separate hydronic systems. The boiler is directly vented so that all the combustion byproducts vent to the outside of the house. The space heating is provided by a radiant hot water system of $^5/_8$" polyethylene tubes (Wirsbo) set within the concrete floor slabs. There are four control zones each circulated by a separate pump (Grundfos) and individually controlled thermostat. This radiant heating creates warm floor surfaces while allowing the room air temperature to stay comfortably cool. During the winter of 1992, with strong 20-30 mph winds and nighttime lows of minus 25°F, the radiant floor heat kept the occupants quite comfortable while indoor air temperatures averaged 66° and humidity levels were between 45-50 percent.

To make optimal use of natural daylighting while still retaining some energy efficiency, we used the best windows we could get. The windows we used were custom manufactured, with fiberglass frames (Owens Corning) and two layers of high performance Heat Mirror™ film (Southwall Technologies) suspended between the two panes of glass. The windows are also filled with argon gas to impede the transfer of heat through the glass. They provide R-values of R-8 at center of glass and R-6 overall, about three times the R-value of conventional double glazed windows. The glazing on the southwest exposure equals roughly 15 percent relative to the square footage of the house. With strong winds from the north and east, we minimized the use of windows on those exposures and built a recessed entryway on the north side. The exterior doors have insulated cores, compression foam weatherstripping and adjustable thresholds.

ReCRAFT 90 allows for a high degree of natural daylighting. The cooling tower and skylights in the building disperse sunlight and provide passive cooling in the summertime. We used spot and track lighting, with energy conserving light fixtures such as low voltage halogen lights that provide full-spectrum light while using $^1/_5$ the energy of a standard incandescent bulb. Full spectrum fluorescents are used in the laundry room, garage, and in the kitchen. Electronic rheostats control light intensity on four of the circuits, providing another way to reduce consumption of energy.

For ReCRAFT 90 we tried to find systems that would reduce the amount of water for flushing toilets and for showering. Instead of a typical 3.5 gallon per flush, we have 1.4 gallon per flush toilets and shower heads that use $2^1/_2$ gallons per minute instead of the typical $3^1/_2$ - 5 gallons per minute. We chose a dishwasher and clothes washer that had variable load settings so that we could adjust the water use according to need. We planted mostly drought-tolerant native species, and limited water intensive turf grass to areas used for social and play activities.

Ventilation, air-conditioning, indoor air quality

A whole-house air to air heat exchanger (Van-EE) is run continuously to provide ventilation throughout the living areas. This air-to-air heat exchanger (or "heat recovery ventilator"), revives indoor air with a constant supply of fresh tempered outdoor air circulated throughout every room of the house. The mechanical ventilation rate is $^1/_4$ air changes per hour (135 cubic feet per minute) and the model in ReCRAFT uses only $^1/_2$ kwh of electricity for each 24 hour period of operation. The cooling tower/lightwell (strategically located at the center of the house) can be opened as needed by the occupants. Prevailing north summer winds, and deciduous trees planted on the west and south exposures also help to keep the house cool.

A frequently asked question about ReCRAFT 90 has to do with the effect of all the "manufactured" products on indoor air quality. Many people have expressed concern that the house would have excessive levels of formaldehyde and other harmful air contaminates. Despite all the different engineered wood products used in ReCRAFT 90, there are few products that contain urea-formaldehyde adhesives. Most of the wood products contain phenol-formaldehyde or isocyanurate adhesives. Indoor air samples were taken in October of 1992 using monitors provided by EPA. Test results showed formaldehyde levels of .03 or .04 ppm in every room but one. The room with a higher reading (.09 ppm) was subsequently checked to try to find the source of this formaldehyde, and it was discovered to have closet shelves made of unfinished particleboard. These shelves were replaced with Medex to bring that room into acceptable levels. A level of .05 ppm or below is considered to be common background level in a home.

Conclusion

Since completion, ReCRAFT 90 has been toured by over 9,000 people; fulfilling our original goal of building a house that could serve as an illustration of "resource efficient" building materials and practices as well as energy efficiency. ReCRAFT 90 has been featured in both print media and on television, and has inspired the construction of other demonstration projects throughout the country.

STATUS ON THE DEVELOPMENT OF A PROTOCOL FOR ASSESSING POTENTIAL BENEFITS OF GREEN BUILDINGS

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Abstract. This paper provides the first public status report on a research effort to develop a general protocol for assessing the benefits of Green Buildings. Green Buildings are buildings designed so as to minimize their negative environmental impacts, maximize the use of renewable and recyclable energy and material resources, and provide a healthy indoor environment for their occupants. Green Building certification is currently being developed by the U.S. Green Building Council through an assessment based on building design and construction according to an established checklist, and on promises, subject to periodic validation, made regarding a building's future operation and maintenance (O&M). But such checklist processes do not analyze or report benefits that the building will have on the productivity of the occupants, its overall positive and negative environmental impacts, or even the benefits the building may have for the community around it. The U.S. Department of Energy believes this additional information is critical because it provides defensible criteria that argue why Green Buildings are preferable to other approaches to building design . Benefits are expressed in terms of the net effect "Green Building" design and construction have on occupant health and well-being, productivity, and business processes for the firm, and are expected to be assessed by a mixture of quantitative and qualitative measures.

Background

The goal of this research project is to establish a background model or protocol for assessing the potentially different life cycle benefits of commercial Green Buildings. A life cycle includes the conceptualization, design, construction, operations, and maintenance of a commercial building. Treatment of the entire life cycle of a Green Building will enable consideration of the full range of potential benefits the building may provide to it's owners and occupants. The protocol's over-arching goals are that it should enable assessment of a wide range of building types and usages, and that it scale to the consideration of groups of buildings, i.e., "Green Communities."

Pacific Northwest Laboratory (PNL)[1] is leading the project, which is expected to last at least two years. PNL staff with backgrounds in architecture, indoor air quality, human factors, and information science are participating. They are being assisted by a graduate intern from University of Michigan at Ann Arbor, and a hydrogeologist from Doremus and Associates.

In order to develop a Green Building benefits protocol, real data are needed to help identify and prioritize parameters and to discover underlying linkages and principles. An ideal source of such data has become available in the green building design and construction of a multi-purpose facility for Phoenix Designs, a subsidiary of Herman Miller Inc. This will be a combined plant, office, and warehouse building in a naturalistic setting in Zeeland, Michigan with occupancy scheduled for October 1995 (1). The chief architect of the new Phoenix Designs building is William McDonough and Partners, who are architectural leaders in the Green Buildings field. The landscape architect firm is Pollack Design Associates, with a history of landscaping with native vegetation. Herman Miller Inc, Phoenix Designs, William McDonough and Partners, and Pollack Design Associates have been instrumental in the success of the research project by providing access to design and construction specifications of the new building, and to the historical information that will enable refinement of the protocol as it is being developed.

Phoenix Designs is a fast-growing re-manufacturer, manufacturer and vendor of office furniture that has been in business for approximately 10 years. Phoenix Designs has a niche market providing "just in time" products for small businesses and nonprofit institutions (Figure 1).

Figure 1: A view of the Phoenix Designs office furniture plant. *Photo courtesy of Herman Miller, Inc.*

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[1] Pacific Northwest Laboratory is operated for the U.S. Department of Energy by Battelle Memorial Institute under Contract DE-AC06-76RLO 1830.

Phoenix Designs currently leases space in two buildings. The company's total quality metrics (TQM) program monitors and inspires the productivity of their manufacturing processes, which operate across three full-time shifts. Other performance data, such as errors in orders, delivery faults, and accidents are tracked through other programs. Employee health and safety records are kept and are being made available to this study, as are energy consumption data and other O&M statistics. More than two years of consistent data and information are readily available for this study, as is future operating information when the new building is occupied. Baseline information about pre-existing conditions of indoor air quality and interior lighting quality in the leased facilities is being gathered at the time of writing of this paper.

On a walk through assessment of the existing Phoenix Designs facility, PNL staff concluded that the working conditions were excellent, morale was high, and management and staff welcomed the benefits study project (2). This provides good starting conditions for the benefits study, as the firm's full cooperation is critical, while it's emphasis on a healthy and efficient workplace and thorough documentation of processes will significantly aid future attempts to distinguish which potential benefits can be traced directly and indirectly to features of the Green Buildings design.

The New Building

The new facility is a combined manufacturing plant, warehouse, and headquarters building (26,942 m^2 [290,000 sq ft]) for approximately 700 people (600 in the plant, 100 in the office). The design considers extension plans for an additional 9,290 m^2 (100,000 sq ft). A number of "Green Building concepts" have been integrated into the design of the new building, including large scale use of daylighting, enhanced indoor air quality, eye-level windows that look out onto natural viewscapes, naturalistic spatial concepts, careful selection of materials and finishes, and environmentally sensitive site planning (Figure 2, Figure 3). Sophisticated HVAC and lighting control systems feature data loggers that will enable tracking of operations and conditions during different shifts and different seasons to minimize energy consumption. The community in which the building resides has been involved in the design process from the beginning, as have the staff that will occupy the building. The construction process is being documented with photographic slides and video.

The new Phoenix Designs building thus demonstrates a multitude of Green Building concepts that with available, high-quality measures of productivity and performance data, provide a seminal opportunity for a definitive benefits study on Green Buildings (2). It also produces an early opportunity to establish a potential benefits protocol generalizable to future Green Buildings studies.

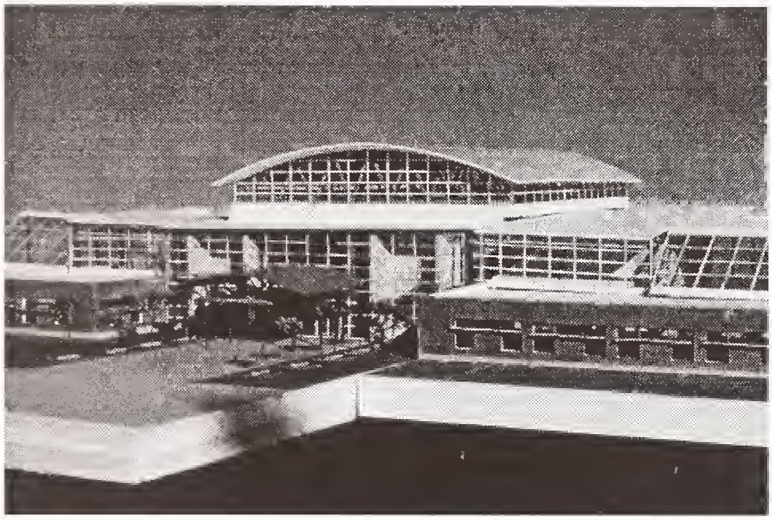

Figure 2: A front-view photograph of a model of the new Phoenix Designs building under construction in Zeeland, Michigan. Office spaces are in the foreground, plant and warehouse areas are in the rear of the building. An interior, landscaped boulevard runs between the plant and office areas. A wellness center is on the second floor. *Photo courtesy of Herman Miller, Inc.*

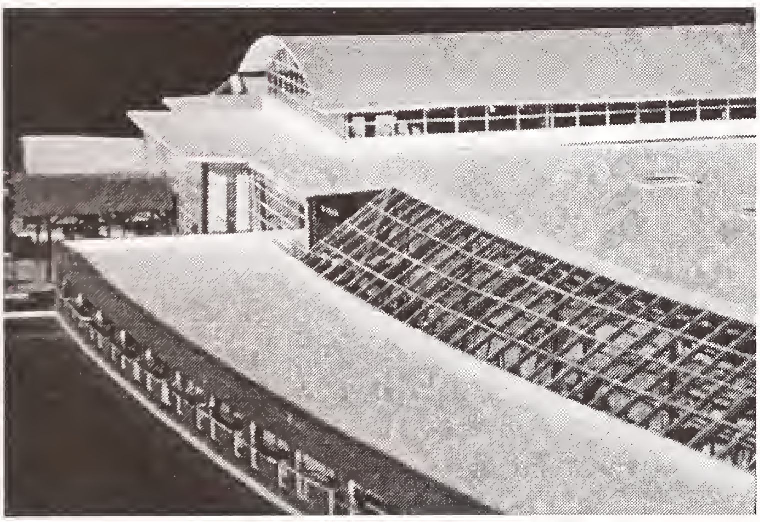

Figure 3: Another view of the Phoenix Designs building model, this one showing the curved mass of the building that reduces visible building mass, and the glazing that provides daylighting of the boulevard. *Photo courtesy of Herman Miller, Inc.*

Why Expect Benefits from Green Buildings?

The idea that energy efficient, environmentally sensitive buildings might produce benefits well beyond their energy savings has lately received a large amount of media attention. But it is not obvious why this should be the case. Why should design from an environmental perspective produce a variety of other kinds of employee, business, and community benefits? We believe that the reasons are both varied and subtle, and are deeper than the current media reports indicate. This is because many of these reports have dealt with the apparent relationship between installation of new energy efficient lighting systems and increased employee satisfaction and productivity, along with the expected decreased electricity bills. This outcome is not overly surprising, considering the lighting system being replaced was often quite obsolete, and was probably not designed for the type of work currently taking place in the buildings studied. In addition, lumen depreciation had no doubt often occurred as the original system aged, with tubes and bulbs not replaced until they expired. That process allowed workers to slowly adapt to conditions of decreasing illumination, remaining unaware of the problem while the reduced lighting conditions increasingly affected their performance.

Replacing an older lighting system with a modern energy efficient one can then put light where it is most useful to the worker, and can greatly improve color rendering, clarity and glare control. Good quality lighting and highly efficient lighting are no longer incompatible, so less watts-per-square-foot no longer necessarily means living with less light. With the improved lighting, people can see their work better, and can work safer, while not being impacted by glare conditions that tend to produce headaches and eyestrain. Furthermore, when the lighting design includes the incorporation of daylight into spaces through windows, skylights, atria and other means, then occupant responses are generally even more positive as long as people have the ability to control excessive light and heat. Because of this wide range of design considerations, we would expect to find that "green" lighting design has positive impacts not only on worker productivity, but also on their psychological and physical well-being.

But energy efficient lighting or HVAC systems alone do not make a Green Building *per se*. Green Buildings combine energy technologies with materials choices, space and site planning, thermal and HVAC controls, and careful design integration of mechanical, environmental, spatial, and humanistic concepts. What is it across all of these disparate aspects of building design and construction that produces different enduring benefits for the buildings' occupants?

At their most basic, Green Buildings also promote contact with green things -- e.g.nature -- and this amenity has been shown in numerous studies to have very positive effects on human health and well-being (summarized in Ulrich [3]). Many of the potential human benefits to be found in Green Building design and construction can be understood by an appeal to the 'Biophilia Hypothesis' proposed by E.O.Wilson (4) and Kellert and Wilson (5). Wilson defines biophilia as "the innate tendency to focus on life and lifelike processes:"

A basic tenet of the Biophilia Hypothesis is that humans are evolved biological beings, with at least a million year prehistory on the African savannahs leading to our modern species, Homo Sapiens. This prehistory involved behavioral, psychological, and physiological adaptations to living in the natural environment. For instance, Wilson (4) speculates that human evolution in a biocentric world created brain structures attuned to extracting, processing and evaluating information from natural settings, events, and occurrences. Fitness in this ancestral natural environment meant the difference between life and death, so it is not unreasonable to expect that people have been somewhat genetically 'tuned' to the natural world.

Elaborations of the Biophilia Hypothesis with respect to landscapes and the presence of nature in the man-made environment have been proposed by Heerwagen and Orians (6), (7). Deriving their perspective from ecological theories of habitat selection, they argued that modern environments that recreate the essential habitability features of the African savannahs are likely to be especially appealing and to have positive impacts on people. Those natural features which fulfill survival-related functional needs, include:

- green vegetation signaling lushness and environmental productivity;
- distant views for surveillance;
- clustered trees with spreading canopies for protection from the sun and inclement weather;
- protected nooks and other enclosures for sleeping, child care, selective retreat and recovery from stress and illness;
- diversity of vegetation for food, tools, medicine, and building materials;
- open spaces with even ground cover for efficient locomotion;
- paths and natural landmarks that provide orientation and location cues;
- changes in elevation for visual access and escape from predators;
- clean water for drinking and bathing;
- the presence of other group members for social and emotional support.

Heerwagen and Orians further propose that the ambient qualities of the environment -- especially light and sky conditions -- intrinsically draw our attention and evoke strong emotional responses because the information they provide has relevance for survival. Being far from home when night is approaching and the sky is threatening is likely to provoke anxiety in most people, even today (especially when nocturnal predators, human or animal, are present). On the other hand, sitting around the campfire when the sun is setting in a clear sky is likely to be comforting and relaxing. The Biophilia Hypothesis thus suggests that daylight is important not only to see but because it is a biologically relevant signal. It is not surprising, then, that access to daylight and environmental information is a strongly desired building attribute. People who work in windowless spaces frequently complain about the loss of daylight and weather information, despite the fact that they usually have enough lighting for work.

When modern analogs of the early human environment are combined with the medical good sense to avoid noxious chemical stressors and other unhealthy agents like airborne particulate and bacterial agents, the basics of most Green Building design are in place. Many of these features are apparent in the design of the Phoenix Designs building. For example, a vignette of the boulevard shows progressive disclosure afforded by the curved mass of the building, daylighting from the overhead (slanted) glazing, naturalistic landscaping of the interior, and a space that encourages mixing between staff and management (Figure 4).

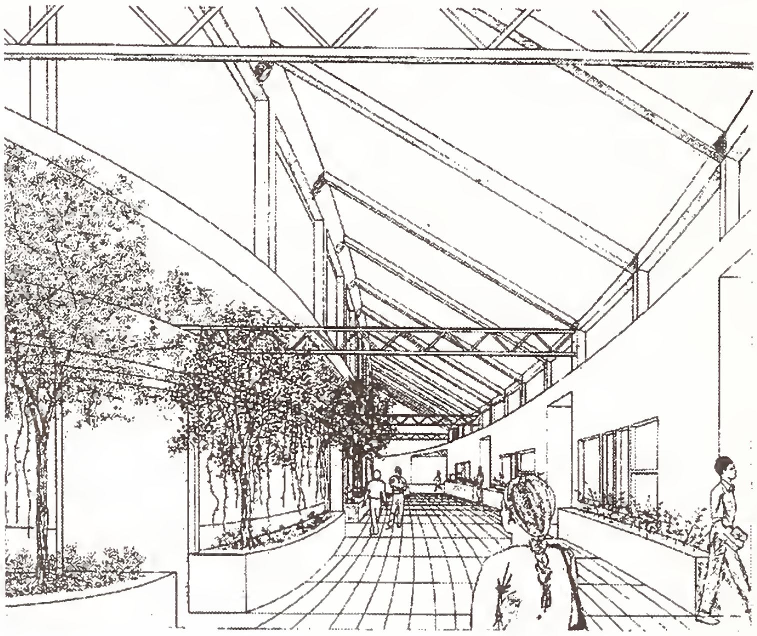

Figure 4: A vignette of the Phoenix Designs boulevard that provides a buffer between office spaces (to the right) and the plant/warehouse areas (to the left). *Source: William McDonough Architects, Pollack Design Associates and Verburg & Associates, Architect.* *__The Phoenix Design Project__, Zeeland, Michigan, 1994.*

In other words, Green Buildings produce benefits for people because they more nearly reproduce, in analog fashion, the positive aspects of the natural environment to which we may be genetically adapted, while avoiding occupant exposure to many modern chemical and biological stressors. This means that Green Buildings tend to create biologically preferred conditions for humans, which consequentially allows them to perform and be their best.

Looked at in more detail than can be presented here, the Biophilia Hypothesis provides the basis for identifying favorable building environmental conditions and distinguishing them from less favorable conditions. It also offers insights into the mechanisms by which beneficial outcomes are produced as well as the kinds of outcomes that may be expected under different conditions (e.g., fear, anxiety, creativity, comfort, pleasure, stress reduction). Therefore, PNL's approach to assessing the benefits of Green Building design will thoroughly consider this hypothesis and other related environment-behavior research by looking at the building as an ecosystem of inter-related places and processes.

The Nature of Green Building Benefits

Benefits to be found in environmental and building designs are usually found in combinations of design features that are mutually supportive and reinforcing of one another. We call these designs *higher-ordered constructs*, for example, windows with naturalistic viewscapes. If we try to be overly reductionistic (for instance, analyze the impacts of windows separately from the outside landscaping), we end up missing the systemic qualities that arise from combinations of features working together.

A narrow focus on a list of specific building technologies and design attributes that comprise the building give rise to a sort of checklist thinking, as with the certification process for Green Buildings described previously. But while handy, this mind set misconstrues the added value that comes about through contribution of the appropriatenesss of all the building technologies and attributes into a functioning whole. A Green Building, like an ecosystem, should be more than the sum of its parts.

A possible trap exists for advocates of Green Buildings who argue for such buildings' worthiness on the basis of immediately demonstrable benefits from employees, such as increased productivity and lowered absenteeism. Even if these are validated, the cynical response can be that values of Green Buildings lie in nothing more than improving working conditions of people; which can be accomplished in many ways without adopting a Green Buildings philosophy.

But an assessment focused on higher-ordered constructs means not having to show immediate benefit from every building element in particular, but rather demonstrating how individual elements contribute to benefits gained from the conditions formed by higher orders of elements in a systemic arrangement. Every design detail or construction feature that can be isolated cannot be expected to directly increase the productivity or health of employees or their job satisfaction. Some of these features may simply add value by stabilizing or extending the range of conditions under which higher order arrangements of details and features generate demonstrable benefits. It may be possible, however, to identify certain "keystone features" that act much like keystone species in an ecosystem -- if they are removed or made dysfunctional in some way, the ecosystem is dramatically altered. Another key aspect of ecosystems that may have an analogy for Green Building design is the web of relationships that keep an ecosystem in balance. The alteration of even one element can have cascading effects throughout the system. To date, buildings have not been analyzed as ecosystems. Thus, many of the subtle impacts of design are missed, particularly those which have unintended impacts, or effects that are removed in time or place from the initiating event and thus are easily overlooked.

In short, a successful Green Buildings benefits analysis protocol will need to be more than just an environmental accounting effort that looks for payback in the cost of a building through adding up a list of particulars. If the Green Buildings philosophy and approach to building design is to be justified and encouraged, it will be through the realization of benefits that accrue on different levels and in different ways to the owners, inhabitants, and community in which the building resides -- and the environment. Some benefits will be quantifiable, such as energy savings; others will be anecdotal or otherwise qualitative. For example, a Green Building could become an environmental educational resource for the schools in its area. What then are the benefits to a company and the community from using a Green Building as a means to teach and demonstrate environmental sensitivities?

Research and Development Strategy

The position of the project staff, based on experience and judgment, is to incorporate the body of work mentioned earlier (references 2--7), Kaplan and Kaplan (8), J.J. Gibson (9), Lantrip (10), and the seminal efforts of many others who have published research on perception, cognition, environment-behavior transactions, spatial theory, and productivity in commercial environments. The theories selected will suggest the environment-building features to study, which in turn will have performance criteria germane to Green Buildings. These criteria will themselves denote specific measures of an explicit quantitative nature (such as thermal comfort ratings or the number of windows), or observations that can be quantified (such as degree of satisfaction with an office furniture arrangement).

As staff progress along this theoretical framework, time is forcing us to act now to capture data about pre-occupancy conditions in the current environment, and information about the conceptualization, design, and construction processes of the new building. These time dependent conditions are of relatively short duration, so educated assumptions must be made about data that will be needed in the future and gathered now or be lost forever. In some cases, we know that certain measures will be needed, such as the productivity measures tracked in the Total Quality Metrics program now in place at Phoenix Designs. In other cases, necessary data such as indoor air and interior lighting quality does not exist. In response, the team is initiating an effort to collect a variety of measures that is expected to be of sufficient quality and quantity. Finally, after going through the process shown in Figure 1, some new, unconventional measures have been developed from scratch that are necessary to meet the needs of assessment suggested by the building as ecosystem theoretical analog. In other words, conventional measures such as square feet of floor space or window area, may not be adequate to describe the environment-behavior transactions needed to comply with the theoretical framework we are developing for the study.

This study is expected to span at least two years (beginning this year), and possibly more, if at all possible. The extended time is needed to collect a significant body of information on the post-occupancy characteristics of the building performance and that of its occupants. After one year of post-occupancy data has been collected and analyzed, staff will develop the assessment protocol. The protocol will then be applied to and validated on a number of other buildings, as a means to revise and tune it. This process will no doubt involve collaboration with other building researchers at universities and firms around the country.

Next Steps

As discussed, a substantial literature review is underway, analyzing past productivity and benefits studies that considered one or more focal areas of the study, or which investigated the physiological, cognitive, and behavioral connections across human, building, and environmental components of our Green Building benefits theory.

As these activities are underway, baseline indoor air quality measures are being defined for capturing current conditions in the existing Phoenix Designs facility. Similarly, a lighting study is being planned. Baseline indoor air quality measurements will include volatile organic compounds, suspended particulate matter (respirable particles), carbon monoxide, and carbon dioxide at a spatial and temporal resolution needed to provide an adequate premove snapshot. Lighting data will include at least vertical and horizontal footcandles on working and circulation surfaces at selected points, and assessments of glare, color rendering, and illumination vectors.

An exploration of the landscaping and hydrologic environment at the site of the new building is being performed by Doremus and Associates. They will analyze the water balance on the new property and evaluate the living landscape water routing through the wetlands and forests created as part of the landscaping plan.

Additional efforts are also underway to collect, synthesize, and analyze historical productivity data, health and wellness data, and design and construction documentation (slides, video footage, design documents) provided by Phoenix Designs.

By the end of August 1995, much of the data and information available from the pre-occupancy phase of the Phoenix Designs company will have been collected and analyzed, along with the results of previous relevant studies. We will base our procedures for collecting data in the new building on those analyses, and then draft a more general protocol for assessing the potential benefits of Green Buildings. If, as we theorize, Green Buildings benefits both reside in and accrue from a building performing in the ways that natural ecosystems do, then both a design methodology and assessment strategy for Green Buildings may be practical and achievable in the near future.

Acknowledgements:

We thank Nancy Foote of PNL for her expert diligence in editing this paper. We also thank Herman Miller Inc., Phoenix Designs, William McDonough Architects, Pollack Design Associates, and other firms participating in the Phoenix Designs project that have been gracious in sharing with us their time and information. Last but not least, we thank Lou Divone of the U.S. Department of Energy Office of Building Technology for his support and collaboration which has made this project possible, educational, and enjoyable for us all.

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GREEN ECONOMICS AND THE BENEFITS OF INCREASING ENVIRONMENTAL AND ENERGY EFFICIENCY

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Abstract. The environment has had a central role in the way businesses have come to be run. This paper discusses full cost accounting schemes that businesses could use to calculate external costs of production and manufacture. It also discusses the tax shift that is occurring in Europe, as well as the "proper" tax shift of pollution taxes and current trends in the practical application of environmental economics and potential gains in productivity and efficiency. Finally, the Green Gross National Product that the Department of Commerce has begun work on is discussed.

I. Introduction and Summary

The environment and environmental regulation have taken a central role in the way businesses are run in the United States. The **National Law Journal** (Jan. 20, 1992) estimated that it will cost $752 billion over the next thirty years to clean up the United States' known hazardous waste sites. Total liability for these sites is over $1.2 trillion according to the University of Tennessee, Hazardous Waste Remediation: The Task Ahead (1991). The Environmental Protection Agency estimates that environmental legislation and regulations impose a cost of compliance in excess of $30 billion per year; another study estimates that industry in North America and Europe together spend over $150 billion in pollution abatement and control per year; and soon, environmental compliance costs are expected to consume between 2.5 and 3 percent of the Gross National Product. These numbers are staggering. Companies must find ways to manage these costs. This liability has so far been the greatest factor in pollution prevention, reuse, and recycling gains.

On the benefits side we are learning that productivity increases from environmental efficiency will soon become one of the foremost motivators in the marketplace. For example, energy and environmental improvements to buildings provide productivity gains of 15-20 percent to the occupants, which is a greater economic gain than the total capital and O&M costs of the building.(1)

An equal gain in benefits is predicted for taxes on pollution to use the free market system to supplant additional command and control regulation. There is a growing consensus for the need for pollution taxes. This approach is preferred now by both conservatives who favor less government and liberals who favor more environmental protection and energy conservation.(2)

The "Big Six" international accounting firms are marketing their proprietary full cost accounting systems by stating that preventing and reducing waste leads to more efficient and profitable business. But how are companies to know what is best to reduce or eliminate in their manufacturing processes? Recently, New Jersey enacted legislation requiring cleaner burning cars by 1999. Automobile manufacturers said this would drive up costs. Regulators contended that it would spur production of revolutionary new automobiles with higher efficiencies and lower emissions. But how should automobile manufacturers meet this requirement? Should they invest in electric car technologies or natural gas technologies?

Environmental cost accounting systems are used to quantify cost activities by correctly pricing all goods and services, including the "full" or environmental costs of providing such goods and services. From that point, for example, automobile manufacturers can best decide how to comply with the New Jersey statute by adjusting their processes or prices; and consumer practices will then change, thus obviating the need for government regulation.

This paper examines current trends in the practical application of environmental economics and the potential gains in productivity and efficiency.

II. The Proper Tax Shift: Going from Additional Command and Control Regulation to Global Pollution Taxes

The growing consensus for this type of global tax shift is its tremendous efficiency versus the prospect of additional inefficient command and control regulation. Existing command and control regulation is enormously expensive, it decreases national productivity, and has tremendously escalated transaction costs paid to lawyers and consultants. In many instances, it has completely broken down due to politics, difficulty of enforcement, and the expense of compliance monitoring with the end result, e.g., the lack of waste load allocations and total maximum daily loads for discharges in the East and Gulf Coast waters.

Pollution taxes address this problem and use the marketplace to ensure comprehensive coverage and benefits far beyond any feasible compliance with command and control rules:

- dramatically increase recycling by internalizing pollution costs, thus making recycled materials more cost competitive;
- dramatically increase pollution prevention;
- dramatically increase new technology development for less polluting activities;
- dramatically increase economic incentives to entities reducing pollution and economic disincentives to those who do not; and
- address many significant pollution sources that are inadequately regulated or not controlled at all, e.g., CO_2 emissions, nonpoint sources, and point sources without total maximum daily loads.

Imagine a plant manager who realizes that over a 15 year period a tax will gradually escalate on the water, air, and land releases from the facility. Obviously this manager will create many new and innovative ways to reduce these emissions, from changing product lines(3) to new ways to eliminate waste.(4) The practice of this hypothetical plant manager will be replicated at other facilities all over the world, thus having the greatest possible improvement in technological innovation for pollution prevention, reuse, and recycling.(5)

Most appealing to conservatives is the prospect that pollution taxes serve as the basis for substantially reducing the size of bloated state and federal bureaucracies that are viewed as highly inefficient and involved in many problems far too complex for them to resolve. Environmental groups also favor this approach because it will economically favor less polluting energy sources in addition to addressing CO_2 emissions and other inadequately regulated pollutants.

A draft ASTM standard has been prepared to achieve a consensus for calculating the tax. The standard does not purport to be based on economic theory that may achieve the ideal external cost. In fact, achieving a consensus on this point may be impossible due to the difficulty in calculating environmental damages, e.g., what is the cost of global warming, global acid rain, global coastal pollution? There is an extensive debate in the economic and legal literature over "proper external costs." The ASTM standard does not attempt to be the solution to this issue.

Instead it uses EPA's costs of pollution control as a surrogate for the external cost, primarily because there is no other accepted measure. It is equitable in scope by covering both point and nonpoint sources. It also is revenue neutral and contains incentives: entities receive a twenty percent tax credit if they emit ten percent less than the prior year, and a twenty percent penalty if they emit the same or more pollution than the prior year.

The standard has a number of cosponsors and is expected to be initiated within the calendar year. European nations have enacted or proposed this type of pollution taxes, and for over twenty years, have assessed effluent charges but at minimal levels not high enough to effectively encourage pollution prevention, reuse, or recycling. The ASTM standard does not tax energy; it just taxes pollution because there is no inherent benefit to pollution.

In addition to the cosponsors to the ASTM standard and governments favoring pollution taxes, the Business Council for Sustainable Development (BCSD) supports the shifting of taxes away from capital and labor and toward value-depleting activities. Also, the World Industry Council for the Environment (WICE) chairman, Rodney Chase, also managing director of British Petroleum, said that WICE favors pollution taxes as an "important part of the armory." The BCSD and WICE are comprised of multinational manufacturers among other entities. Similarly, the American Petroleum Institute favors marketplace mechanisms for pollution control and pollution taxes is one of these mechanisms.(6)

III. Full Cost Accounting Schemes

The "Big Six" accounting firms have developed proprietary methodologies to perform full cost accounting. They can be broken down into components.(7)

A. Environmental Management Systems

Before a company decides on a cost accounting system, it should determine the goals it seeks to accomplish. A company's environmental management system will make these determinations, and can take varied forms: recycling and pollution prevention, responsible purchasing, innovative manufacturing technologies development, and/or community involvement. Environmental management systems (EMS) should set measurable goals and objectives, which can be based entirely on internal criteria, on published external standards, or a combination of both. ASTM Committee E-50 has just published a standard for evaluating Environmental Management Systems.

B. Environmental Information System (EIS)

Once a company sets its environmental goals, it should monitor its progress towards those goals. The data the information system should provide range from permit renewal deadlines to complex sustainable development cost-benefit models. In order to quantify the real internal and external costs and benefits, the information system must be integrated into the cost accounting system. The usefulness of the information gathered will depend on the scope of the company's overall environmental information system and the sophistication of the analysis it applies to environmental issues and costs.

C. Environmental Cost Accounting Systems (CAS)

Once a company has determined its environmental goals and the information system it will utilize, it should choose an environmental cost accounting system.

1. Environmental Costs and Conventional Cost Accounting

Many cost accounting systems fail to assign environmental costs to the products and processes that generate them. To utilize these methods and still be in a position to manage environmental issues effectively, a corporation should have accurate information on environmental costs.

These systems must at least focus on whether environmental (1) costs are capitalized or expensed; (2) segregated into sufficient detail to aggregate specific costs for certain anticipated uses, such as third-party litigation, fines, and penalties; and (3) monitored, e.g., payroll associated with environmental compliance program, environmental audits and testing, environmental fines, penalties, and cleanup costs, waste disposal costs, reserves set aside for contingent liabilities, and revenue lost because of negative public relations.

The major problem with conventional non-environmental accounting system is that they do not accurately allocate costs of production. The reason is that costs arising from emissions, effluents, and solid waste are treated as overhead. The costs are aggregated in a cost pool and allocated to products on the basis of such measures as labor or machine hours. The results are that a product that results in high pollution but requires little man hours may be allocated a small amount of overhead, and an underestimated cost; also, because investment costs are charged to the facility while savings are not, a facility manager may underestimate the profitability of such investments.

2. Activity-Based Costing

To solve the problems of conventional cost accounting, a company could implement activity-based costing. This system accumulates and reports costs by activities or processes. It also provides a blend of the goals of the environmental management system with the information collection and allocation abilities of the cost accounting system. One way to implement such a system is to establish sub-accounts to the general ledger which can allocate to various activities in the appropriate proportion. A second approach is to mirror the actual flow of costs through an organization. Activity-based costing does not reflect the true environmental cost as is intended by total or full cost accounting.

3. Total Cost Assessment and Full Cost Accounting

This system moves beyond activity-based costing by including managerial accounting systems and investment analysis/capital budgeting. Thus, it includes information from the cost accounting system as well as analyses of investment and capital budgeting information. This system has been selected by EPA as the preferred system for evaluating pollution prevention activities. Total cost assessment is a generic description for long-term comprehensive financial analysis. Full cost accounting is a method of managerial cost accounting that allocates direct and indirect environmental costs to a product, product line, process, service, or activity.

4. Life Cycle Assessment

So far, each of these cost accounting systems has had an internal focus. Life cycle decision-making aims for productive and efficient stewardship of resources, and looks to impacts external to a company. It starts at the extraction of resources for a product and continues to where the product goes after its useful life, e.g., to a landfill or recycled.

According to the American Society for Testing and Materials draft life cycle assessment standards, a complete life cycle assessment consists of four components:

- goal definition, scope, and valuation -- providing project/problem definition, setting boundary conditions for the analysis, giving a clear statement of the values used by the assessor and the assumptions and uncertainties used, and establishing the objectives of the study. By values we mean, for example, which environmental and energy impacts should be given the greatest weight.
- inventory -- quantifying energy and raw material requirements, air and water emissions, solid waste, and other environmental releases and energy demands throughout the life cycle of the product.
- impact analysis -- characterizing and assessing environmental and health effects of energy, materials, and emissions identified in the inventory.
- improvement analysis -- systematic evaluation of opportunities to reduce the environmental impact associated with energy and raw materials use and emissions throughout the life of the product.

ASTM life cycle standards are intended to be a means for identifying environmentally preferable products. ASTM standards with narrower scopes also identify these products and can serve as a basis for environmental labelling, e.g., draft ASTM standard for environmentally preferable cleaning products.

5. External Costs and Benefits

Cost accounting systems incorporating life cycle assessment must be able to integrate externalities. Currently, most cost accounting systems have incorporated life cycle assessment into their systems by creating formulas to internalize externalities. When this is done, the incrementally added environmental cost is the amount where the environmental damage cost avoided is equal to the marginal abatement or mitigation cost.

6. Sustainable Development

This is the most comprehensive environmental management doctrine. At the level of the corporation, this would mean adding value without simultaneously causing environmental and other consequences damaging to world development.

Companies should make use of a full cost accounting system for several reasons. Foremost is that knowing relevant costs of production and having the capability to manage them will provide a distinct competitive advantage. This is because environmental cost accounting allows companies to identify environmental costs and benefits that normally are buried in overhead accounts. The company can then trace them directly to specific products or processes and make a more fully informed decision on how to reduce costs.(8)

IV. Green Gross National Product (GNP)

The Department of Commerce's Bureau of Economic Analysis (BEA) has been developing an accounting system to cover the interactions of the economy and the environment,(9) informally known as the Green GNP. It is intended to be a national and international measure of natural resource depletion and degradation, e.g., "sustainable income." The Bureau stresses that the existing systems of national economic accounts are the premier tools for analysis and decision-making. This new system, called Integrated Economic and Environment Satellite Accounts (IEESAs)(10) supplement, rather than replace, the existing accounts. The reason for establishing such a framework was to establish a basis for more informed analysis and decision-making in identifying and quantifying the interaction between the environment and the economy.

The analytical basis for forming IEESAs was to measure the interactions between the environment and the economy. BEA defined economy as human activities related to income, production, consumption, accumulation, and wealth. The environment was defined as being made up of biological resources, subsoil resources, land, water, and air.

The economy uses these natural resources in a variety of ways that can be placed in two classes. When the economy uses a natural asset and permanently or temporarily reduces the asset, the reduction is called depletion. When use of the natural asset reduces its quality, this is called degradation. In addition to these, there are feedback effects. For example, overfishing today will result in future reduced yields. With environmental assets, the feedback effects can be quite complicated and affect other industries and consumers.

Integrated economic and environmental accounting attempts to provide a picture of these interactions. The accounts developed by BEA highlight the fact that economic sustainability depends on environmental sustainability and provides data to help analyze the costs and benefits for decisions regarding the economy and the environment.

IEESA is built upon the United Nation's System of Environmental and Economic Accounting (SEEA), which draws on the materials balance approach to present the full range of interactions between the economy and the environment. Just as the IEESA is meant to supplement the traditional national accounts, the SEEA was designed to supplement the System of National Accounts (SNA), which is the model upon which the traditional national accounts are based.

The SEEA has four stages. Stage A disaggregates environmentally related economic activities and assets. It focuses on actual expenditures intended to prevent or repair degradation. It includes a detailed breakdown of the stocks of natural resource assets and changes in these stocks. It also shows the supply and uses of these resources. Stage B physically maps the interaction between the environment and the economy. It provides the physical quantities to which prices are applied to derive the economic values included in the economic accounts. Finally it links the physical quantities to monetary values.

Stage C uses alternative valuation techniques to show the interaction between the environment and the economy. It does this by estimating maintenance costs to maintain the present level of environmental assets and contingent valuation, or the willingness to pay for reduction in depletion and degradation. It also shows environmental effects on the measures of national production, investment, income, and wealth. Stage D consists of further extensions of SEEA. They include household production and the use of recreation and other unpriced environmental services. This stage requires much more research.

IEESAs were built on this framework developed by the U.N., and thus learned some valuable lessons. First, such accounts should focus on a specific set of issues. Second, they should be done as satellite accounts because of the statistical uncertainties.

The IEESAs have two main structural features. First, natural resources and environmental resources are treated like productive assets. Along with structures and equipment, these assets are treated as part of the Nation's wealth. The flow of goods and services from them are identified and their contribution to production is measured. Second, the accounts provide substantial detail on expenditures and assets that are relevant to understanding and analyzing the interaction.

The first IEESA is the asset account. This account presents stocks at a certain point in time, as well as presenting flows related to assets over a period of time. This table gives the opening stock; the total net; the decrease due to depletion, degradation, or depreciation; the increase due to capital formation; change to due to revaluation or other; and the closing stocks. This presents the nonfinancial value that BEA would try to include in asset accounts.

The second IEESA account is a production account. This combines the flows from the asset account with the flows in a production account, and explicitly includes (1) use of natural resources and environmental services in production through entries for degradation and depletion, and (2) additions to stock of natural and environmental assets through entries for investments that add to stocks of developed natural resources or that restore stocks of environmental assets. Much work must be done to complete these tables. In addition, SEEA calls for parallel quantity tables to be developed, as well as the extension of the integrated national accounts within BEA's regional and input-output programs.

BEA's plan for working on the IEESAs consists of three phases. The first is ongoing. It consists of BEA's work on mineral resources, primarily proved reserves. Phase two calls to extend the process to renewable resources, such as trees on timberland, fish stocks, and water resources. Phase three calls for BEA to include the economic value of the degradation of clean air or water or of the value of recreational assets.

Admittedly, the Green GNP is a tremendous challenge given the economic and environmental uncertainties. However, over time its accuracy can improve and provide a useful national indicator of the country's environmental health and sustainable income.

V. The European Tax Shift

Jacques Delors, in his European Union (EU) White Paper on Growth, Competitiveness and Employment (1993), stated that "[i]f the double challenge of unemployment and pollution is to be addressed, a swap can be envisaged between reducing labor costs through increased charges." In January of this year, the British Prime Minister's Panel on Sustainability called for a gradual move away from taxes on labor, income, profits and capital towards taxes on pollution and the use of resources.

Political support for this sort of "eco-nomic tax reform" (ETR) has been gaining steam in Europe. It was heavily supported by all parties in the recent German elections, but heavy users of energy in industry have blocked progress so far. The Ecological Tax Reform Association (ETRA) has recently been formed to work with those groups who oppose these taxes and to mobilize the majority of German industries that would gain from an ETR.

A recent study done by the influential German Economic Research Institute showed that a unilateral ETR program that raised energy prices by seven percent per year for fifteen years, and recycled the revenues to industry and households, would not damage competitiveness, would cut energy consumption by twenty-one percent, create 500,000 new jobs, and favor the poor over the rich. Studies in the Netherlands, Belgium, and France show similar results.

Specific ecotaxes are common in Europe today. Pesticides, batteries, landfill waste, water, and energy are all taxed. But in some of the European countries with the highest income tax rates, ETRs have been used to reduce those income taxes.

In the 1991 Swedish tax reform, Sweden imposed a carbon/energy tax and other pollution taxes and correspondingly reduced the top income tax rate from eighty percent to fifty percent, and reduced the average taxpayer's tax to thirty percent. Swedish industry won an exemption, however, when the EU failed to adopt its own CO_2/energy tax.

In 1994, Denmark enacted an ETR scheme that raised taxes on energy, transport fuels, water, waste, and shopping bags, with a corresponding reduction in the income tax average from fifty-two percent to forty-four percent. Danish industry was given large exemptions and incentives to save energy and develop renewable energy supplies. Green taxes are set to rise until 1998 to maintain the tax yield despite the corresponding desired reduction in energy and resource consumption. Norway has introduced elements of this tax. The Netherlands, Austria, and Switzerland are also planning to introduce new energy taxes with corresponding reductions in labor taxes and incentives for investment.

VI. Conclusion

We are witnessing a revolutionary change in how we deal with environmental problems. It is consumer and market driven and will not decrease due to the strong connections of pollution to chronic health hazards such as cancer, and the pervasive desire for an improved quality of life. Consumer demand for a cleaner environment will grow even stronger now that we know of the substantial gains in productivity and potential reduced health care costs from increases in environmental efficiency.

It is now politically correct for corporations to be publicly proactive in protecting the environment; the age of environmental marketing has emerged but was unheard of five years ago. Each new generation increases in its support for global environmental protection. This climate provides a unique opportunity to build on these great efficiencies today for a cleaner, healthier, and more productive world tomorrow.

1. Rocky Mountain Institute and the Department of Energy, "Greening the Building and the Bottom Line," as peer-reviewed by the U.S. Green Building Council (1994).

2. Personal communications with the Cato Institute, National Policy Analysis Institute, American Enterprise Institute, Natural Resources Defense Council, U.S. Green Building Council, Merck Family Fund, and National Audubon Society (1994 and 1995).

3. "Full Cost Accounting Programs of Dow Chemical Corporation," Paper delivered by John DeFazio, Dow, at the July 1994 U.S. Green Building Council meeting, Washington, D.C. Dow's "full cost" evaluation of its company resulted in the elimination of whole product lines.

4. In this regard, Herman Miller Corporation is an international leader in furniture manufacturing and waste reduction, and has almost achieved its goal of eliminating all waste from landfills.

5. Personal conversation with D. Berg, Office of the Undersecretary for Science and Technology, U.S. Department of Commerce (March 1995).

6. API letter to the U.S. Green Building Council, June 1994.

7. Russel, William G. et al, Coopers & Lybrand, "Environmental Cost Accounting: The Bottom Line for Environmental Quality Management," Total Quality Environmental Management, p.255, Spring 1994.

8. See Matrix of EMS/CAS Goals, Russell, William G. et al, Coopers & Lybrand, "Environmental Cost Accounting: The Bottom Line for Environmental Quality Management," Total Quality Environmental Management, p.255, Spring 1994.

9. See "Integrated Economic and Environmental Satellite Accounts," Survey of Current Business, Department of Commerce, p.33, April 1994; "Accounting for Mineral Resources: Issues and BEA's Initial Estimates," Survey of Current Business, Department of Commerce, p.50, April 1994.

10. Satellite accounts are frameworks designed to expand the analytical capacity of the national accounts without overburdening them or interfering with their general purpose orientation. They organize information in an internally consistent way that suits the particular purpose for which they are created, while maintaining links to the existing national accounts.

DEVELOPMENT OF THE ANDERSEN LIGHTHOUSE FOR THE WAL-MART ENVIRONMENTAL DEMONSTRATION STORE

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Abstract

This paper reports the process and methodology the Andersen Corporation used to develop and evaluate daylighting systems for a Wal-Mart environmental demonstration store. Evaluation and development of these systems took into account the resultant energy performance, light quality and aesthetics. Ultimately, the four lighting scenarios listed below were simulated in the DOE2.1D Energy Analysis Program in order to compare energy performance:

1. Electrical lighting and standard plastic bubble skylights,
2. Electrical lighting and Andersen Lighthouses with a linear optical lens,
3. Electrical lighting and Andersen Lighthouses with a radial optical lens, and
4. Electrical lighting only.

Introduction

This project began in February of 1992 when Wal-Mart asked the Andersen Corporation to assist them in evaluating the possible incorporation of daylighting systems into an environmental demonstration store in Lawrence, Kansas. Daylighting was identified as one of several environmental strategies that could improve the quality of the environment and the overall energy performance of this retail building.

Andersen worked with Lawrence Berkeley Laboratory to determine the feasibility of incorporating daylighting into a retail application. Using existing Andersen skylight products in several design configurations and a simple plastic bubble skylight, the systems were modeled and physically tested. An energy analysis was done using the DOE2.1D Energy Analysis Program. Although energy savings would be achieved under each of the systems, the results led Andersen to pursue new and innovative technologies in order to provide a more energy efficient Daylighting solution for a retail environment.

Andersen assembled a team to develop an innovative daylighting system to meet the needs of Wal-Mart. The team consisted of members from: the Advanced Research Groups at Andersen, the Solar Optical Products Group at 3M, The Weidt Group and BRW Architects. Once again, extensive physical and computer modeling were used for evaluation and analysis.

Defining an Appropriate Daylighting System for a Retail Environment

We were interested in providing a product that would not only meet energy requirements but also create an environment beneficial to customers and employees. The benefits we wanted to achieve through daylighting the environment were to portray the products in a favorable light, potentially increase sales, increase productivity and decrease employee absenteeism. The following are some of the goals and/or requirements used in developing a daylighting system for Wal-Mart:

1. A target illumination of 75 foot candles,
2. Even illumination throughout the space,
3. Improved color spectrum for truer product rendition,
4. Visual connection to the sky,
5. Reduction in electrical lighting energy consumption,
6. A minimum number of roof penetrations, and
7. A reasonable payback period.

Data Collection

The team generated several significantly different ideas for new daylighting systems. In all, five new daylighting designs were evaluated against one another and to a simple bubble skylight for quantity, quality, and distribution of daylight. Scale model testing ranged from 1/16th to 1/2 scale depending on the physical and optical characteristics of each unique design. Physical testing was conducted outdoors under both clear and cloudy conditions and indoors under direct beam component conditions. Data was collected on 6'-0" (1.83m) intervals at 30" (.76 m) above the floor on an 8 by 8 square resulting in a 2,304 square foot area (214 m2). Hourly readings were taken for one day for the months of March, June and December. Three-dimensional surface graphs were created for each hour of data collected. Testing was done in both a white and a black model. The functional goal of the physical model testing was to compare various designs and to verify computer simulations. The Andersen Lighthouse design was chosen from the five designs for further development and was then used to complete the energy analysis.

Andersen Lighthouse Illuminance Data

Simulated: Date: 6/21 Time: 12:00 noon
Simulated Location: 38 N. Latitude

Direct Beam Radiation
Multiple Units, 30" off of floor, 6' on center

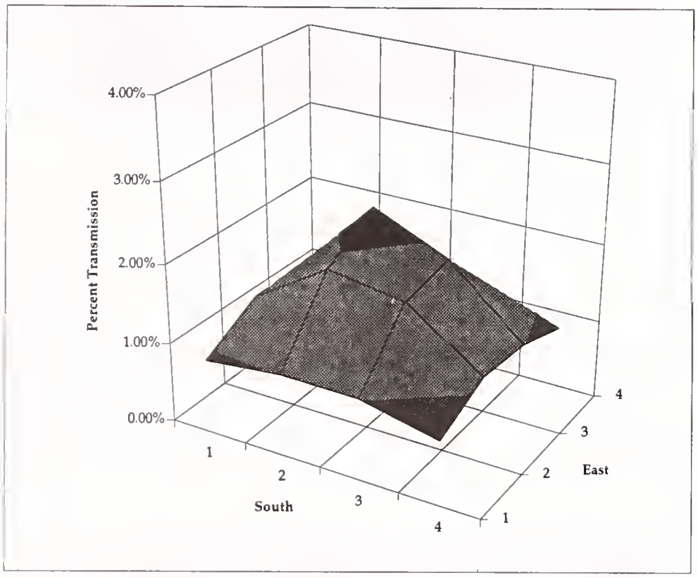

Fig. 1. Three-Dimensional Surface Graph

Daylighting System Description

The three daylighting system designs considered in this energy analysis included two versions of the Andersen Lighthouse and a Naturalite brand skylight. The only difference between the Andersen Lighthouse versions was the lens design. One had a linear optical lens and the other a radial optical lens. The Naturalite skylight, Figure 2, consisted of two layers of exterior grade acrylic in a hipped-roof form on a four foot by eight foot extruded aluminum curb. The exterior, clear acrylic, and the interior, translucent white acrylic, have a combined transmission efficiency of approximately 41%.

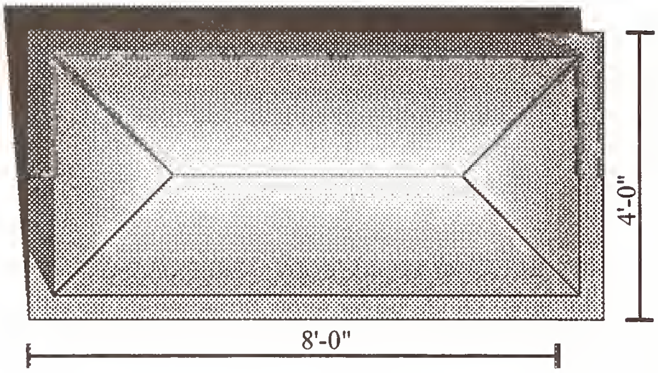

Fig. 2. Naturalite Skylight Plan View

Each of the two Andersen Lighthouse versions, Figures 3 and 4, includes two fiberglass shells separated by an average of 3.5” (8.9 cm) of non-toxic foam insulation. The solar aperture is comprised of a 1” (2.5 cm) dual-pane insulated glazing with an inner acrylic optical lens (either a linear optical lens or a radial optical lens). The foot print of the unit is approximately 4 foot (1.22m) by 8 foot (2.44), similar to that of the Naturalite skylight.

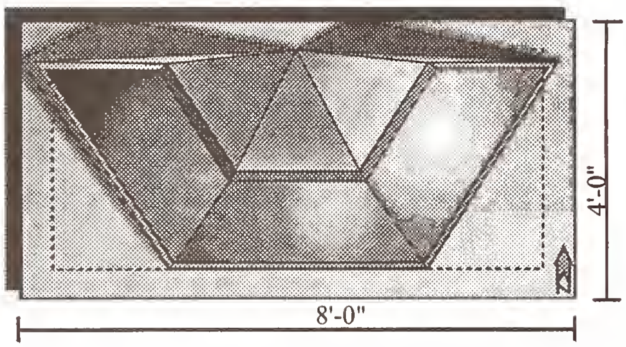

Fig. 3. Andersen Lighthouse Plan View

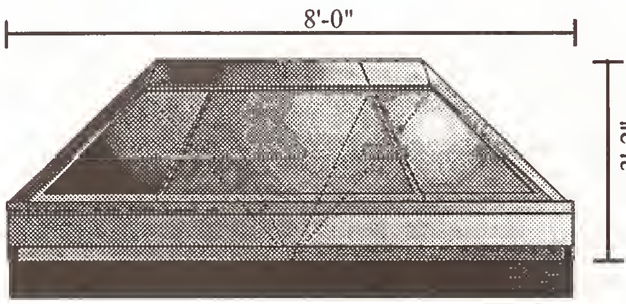

Fig. 4. Andersen Lighthouse South Elevation

The Naturalite has a shallow rise in its hip form but basically behaves as a horizontal aperture. The Andersen Lighthouse has a steeper angle and taller form. The three solar collecting, trapezoidal faces looking southeast, south and southwest are angled up from the horizontal at an angle of 50°. Behind each of these apertures is a reflector. The three reflectors taper to a point inside the Andersen Lighthouse. Table 1 provides a summary of the physical characteristics of the Naturalite skylight and the Andersen Lighthouse as they pertain to energy performance.

Table 1. Comparative Physical Characteristics of Daylighting Systems

		Andersen Lighthouse	Naturalite®
Window Unit	Glazing Area (sf)	19.5 (1.81 m^2)	27.5 (2.55 m^2)
	Total Area (sf)	29.0 (2.69 m^2)	32.0 (2.97 m^2)
	U-Value (Btu/h-sf°F)	0.35 (1.99 w/m^2c)	0.67 (3.80 w/m^2c)
	Shading Coefficient	0.49	0.41
Wood Framing	Area (sf)	7.6 (0.71 m^2)	NA
	U-Value (Btu/h-sf°F)	0.252 (1.43 w/m^2c)	NA
Expanded Poly-styrene Insulation	Area (sf)	46.3 (4.30 m^2)	NA
	U-Value (Btu/h-sf°F)	0.051 (0.29 w/m^2c)	NA

Notes:

1. Unit U-values derived using WINDOW 4.0
2. Shading Coefficient data for the radial lens glazing was not available for this study. The radial lens simulations used the same shading coefficient as determined for the linear optical lens. Although some differences in angular reflectance exists between the two lens materials, information suggests these differences have a minimal effect on the overall energy performance given the lens is located as the fifth and sixth surfaces in the total glazing assembly.

Building Description

The Wal-Mart environmental demonstration store consists of a single floor construction with a gross floor area of 121,856 square feet (11,320m2) and an inside height of approximately 20 feet (6.1). The building is divided into a main sales area utilizing 80% of the floor area and several walled-in perimeter rooms in the remaining floor area. Information about the building and its expected operation was obtained from many sources including:

1. Building plans from the Architect of Record,
2. Preliminary DOE2 energy analysis model from Lawrence Berkeley Laboratory,
3. HVAC details from the HVAC Contractor and Engineers ofRecord, and
4. Utility information from Western Resources.

In cases where information was unavailable, logical assumptions were made in order to complete the study. The building operates at a reduced level during the evening hours. All load scheduling information was extracted from the preliminary study prepared by Lawrence Berkeley Laboratory.

The Wal-Mart demonstration facility has several energy/cost-savings features which make it different from a typical warehouse retail building including:

1. Energy efficient fluorescent llighting at 1.33 W/sf (14.32 w/m2),
2. Ice storage for cooling peak reduction, and
3. Heat recovery ventilation.

Based on the building plans, the HVAC system was modeled as a VAV system with electric heat and zonal reheat. An economizer was used to supply 100% outdoor air when the system called for cooling and the outdoor temperature was sufficiently low. Other features included a heat recovery system for outside air, and a cold storage tank for cooling peak reduction. These combined features have a significant impact on the savings afforded by the use of daylighting systems.

Energy Analysis

The experimental data collected was coupled with hourly cloudiness factors from the Topeka, Kansas TMY weather data and ASHRAE solar insulation data to develop statistical probability models for hourly daylighting performance for each daylighting system. The resulting tables were converted into hourly lighting use schedules and used to determine the degree to which electrical lights could be dimmed. The hourly lighting use schedules were then entered into the DOE2.1D Energy Analysis Program to estimate building energy use and cost by considering both the thermal and electric lighting reduction effects of incorporating daylighting.

Results of the illuminance analysis included a breakdown of interior illuminance by time of day and by sky condition for all systems analyzed (Figures 5-6). DOE2.1D results included a breakdown of energy consumption by end-use (heating, cooling, lighting, etc.) and energy costs for the entire building.

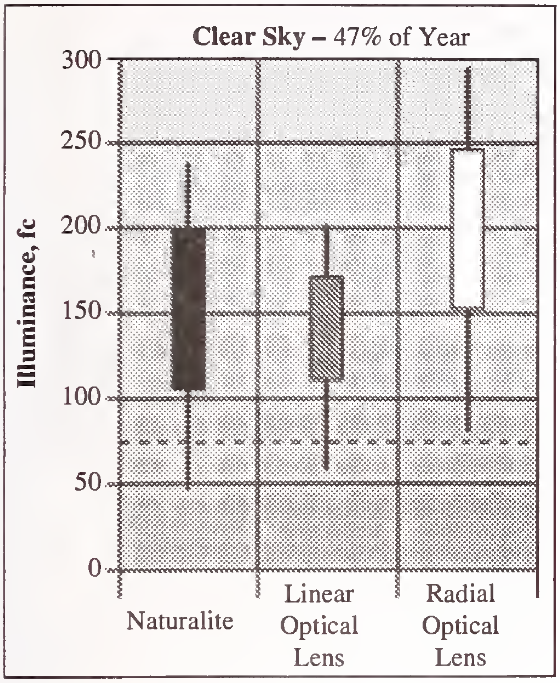

Fig. 5a. Range of Annual Illuminance from 9 AM to 3 PM

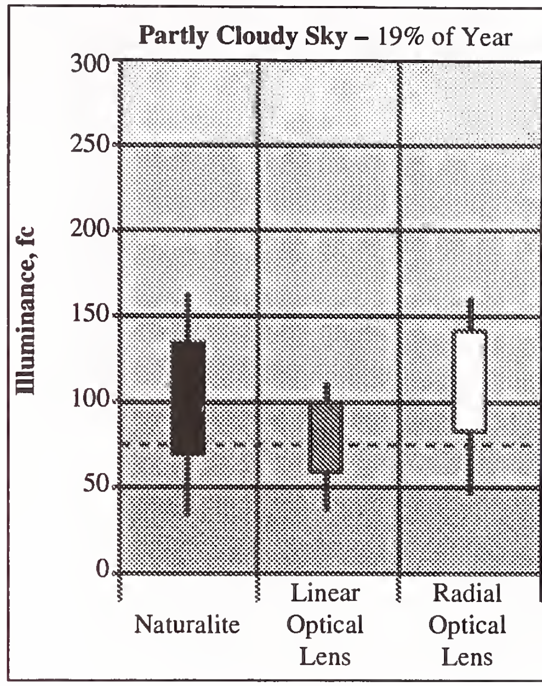

Fig. 5b. Range of Annual Illuminance from 9 AM to 3 PM

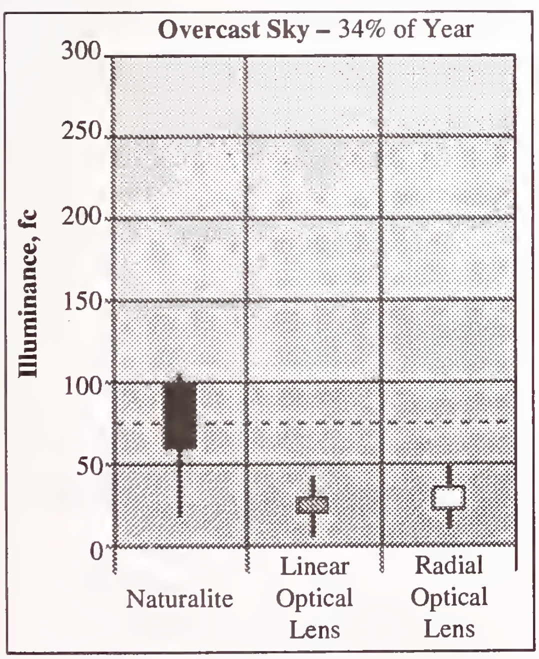

Fig. 5c. Range of Annual Illuminance from 9 AM to 3 PM

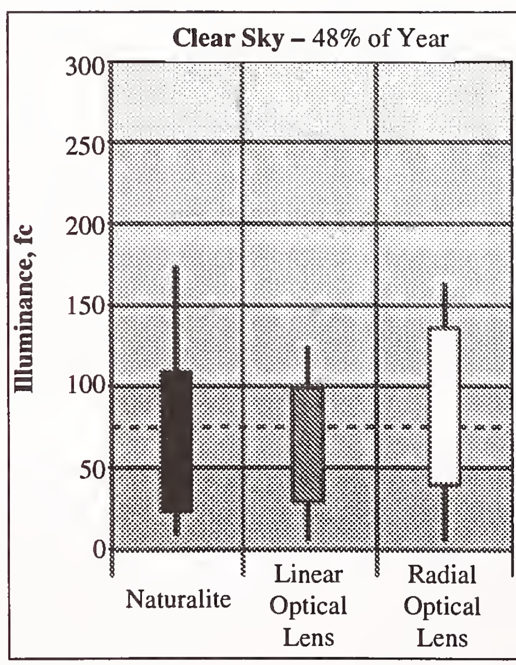

Fig.6a. Range of Annual Illuminance from 6AM to 9 AM and 3 PM to 5 PM

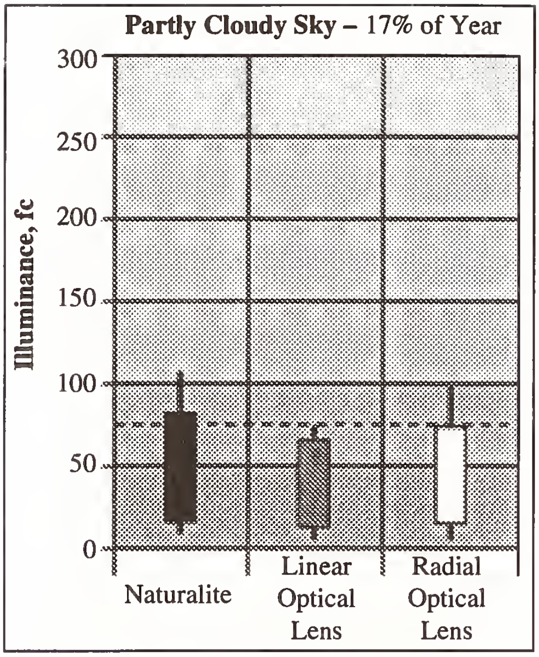

Fig. 6b. Range of Annual Illuminence from 6AM to 9 AM and 3 PM to 5 PM

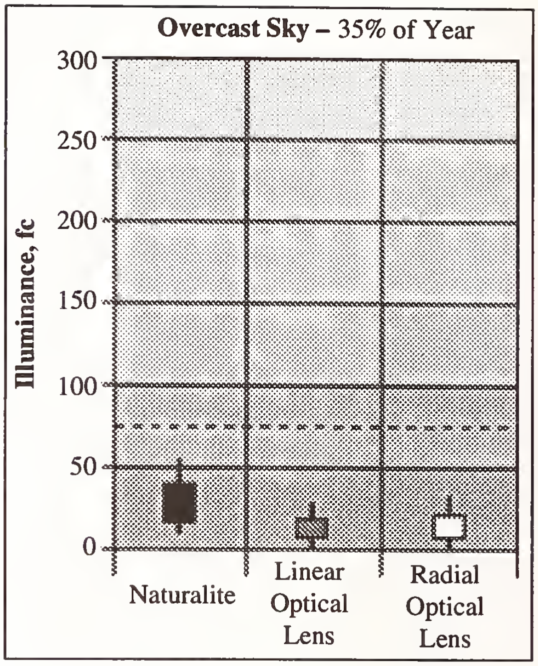

Fig. 6c. Range of Annual Illuninence from 6AM to 9 AM and 3 PM to 5 PM

Conclusions

All three daylighting systems save approximately the same amount of energy and energy costs for the "statistically average" year for Lawrence, Kansas. During most daytime hours, all three systems, under clear sky conditions, save the same amount of electric lighting energy. In spite of their differences in performance under clear sky conditions, lighting values above the target level do not result in greater lighting energy savings. Because the Andersen Lighthouses have nearly a third less glazing area and better insulation than the standard skylights they provide better heating and cooling performance as compared to the standard skylight. However, because the standard skylight has better lighting energy savings performance under overcast sky conditions than either Andersen Lighthouse, the net energy savings for all systems is nearly equivalent for this particular application and site.

The resultant light quality and aesthetics also need to be considered in the overall evaluation of the systems. The color rendition resulting from the Andersen Lighthouse is truer to the outdoors and its changing conditions thus allowing for a more natural environment. The Naturalite skylight's color rendition is directly related to that of the milky colored inner acrylic panel and stays constant irrelevant of sky condition. The clarity of the lens material in the Andersen Lighthouse also allows a direct visual connection to the sky unlike the Naturalite skylight. The Andersen Lighthouse offers much more in the area of light quality and overall aesthetics.

The Andersen Corporation continues with its efforts to develop new and innovative daylighting systems. A second generation of the Andersen Lighthouse is scheduled to be installed in the second Wal-Mart environmental demonstration store in the City of Industry, California in the fall of 1995. These systems have and will continue to be evaluated not only on the overall enegry performance but also on the systems resultant quality and aesthetics of light delivered.

Woodfiber-Plastic Composites in Window Applications

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Abstract: Wood fiber-thermoplastic composites represent a class of materials with cost/performance qualities well suited to fenestration components. In addition, the aspects of recyclability, waste utilization, and solid wood replacement make these composites an ideal choice as the construction industry becomes more environmentally conscious. The Andersen Corporation is currently profile extruding a wood fiber-thermoplastic composite for use as door sills. Raw materials for these components were formerly waste products for the company. Physical properties of the resulting composite are presented in light of specific requirements for fenestration components and other structural applications.

In 1991, faced with a lumber supply situation that had become increasingly tight, the Andersen Window Corporation decided to develop a material to serve as a replacement to solid wood in its products. The result of the research since then has been a wood fiber-thermoplastic composite that the company views not only as a replacement to solid wood in its products, but a different and better material with which to make windows.

Andersen makes yearly purchases of about 100 million board feet of lumber for its product manufacturing needs. The effort to develop a composite material for use at those quantities is definitely beyond the Andersen's previous experience. Therefore, the services of Aspen Research were enlisted. Aspen is an organization of about 80 scientists and technical professionals who perform contract research for private industry in a project format. Its headquarters are in New Brighton, Minnesota. Aspen provides the technical expertise in research and testing methodologies to the project. In addition, because focus was placed on the use of solid waste streams in the product, a $100,000 matching grant was provided (at least for the project phase I'll be discussing, today) by the Minnesota Office of Environmental Assistance, formerly the Minnesota Office of Waste Management. Andersen was responsible for major funding as well as providing application expertise to the material development.

The largest by-product of wood window manufacture is sawdust. Most of this is created by the process of lineal milling window profiles. Andersen produces about 100 million pounds per year of clean pine sawdust. Clean sawdust is utilized to heat its plant, and what can't be used in that manner, is shipped to Northern States' Power Company for use in the generation of electricity. However, Andersen's most popular line of windows is its vinyl-clad wood product called Permashield, consisting of components made of a wood core with about .040" vinyl cladding. Whenever these components are cross-cut, end-milled or routed, the result is a sawdust stream that contains about 5% PVC. These streams are called dirty sawdust. These dirty sawdust streams can not be burned and, until this project, wound up being land-filled.

Another form of waste generated during the extrusion of a vinyl clad wood product is the scrap vinyl produced during process start-up and shut-down. Although PVC is a thermoplastic and can be re-extruded, the wood contamination it picks up during the Perma-shield process makes it unusable for Andersen's prime product and of little value as scrap. This waste stream is termed secondary PVC.

The first step in developing a wood fiber-thermoplastic composite to serve as a substitute to solid wood in the framing of windows was to characterize the specific requirements for such a material. The material requirements are highly dependent on the particulars of the window component in question, but two categories of requirements are common to all components. One of those categories is structural strength; the other is product appearance.

In terms of quantifying structural stiffness, the flexural modulus is an especially useful material property in window applications. However, not all window components require the structural stiffness (or flexural modulus) that wood provides. Many window components are simply trim pieces, and so require relatively low modulus values (500,000 to 800,000 psi, assuming a hollow profile). Window frames need to be stiffer (800,000 to 1,800,000 psi), but since they are fastened to the rough opening of a home, framing studs provide the structural strength during product usage. Window sash are the components that support the glass area of a window. Window performance standards specifically address the amount of allowable deflection that these components undergo when the glass area is subjected to given wind loads. Window sash components have high stiffness requirements (>1,800,000 psi).

In the same way, appearance requirements for window components can be grouped into three general categories. It is desirable for window components visible at the interior of the home to have the warm, natural look of wood. Exterior components must resist ultra-violet light and other elements of weathering. The architectural styles of this country dictate that these surfaces be a single, solid color. Finally, some window components are used in areas of the window that are truly neither interior nor exterior. These components are buried under other components, so that their appearance is not important.

The low structural/non-appearance category of window components represented the simplest application to satisfy; therefore, initial research was performed around products from this category. Although there are several specific Andersen window components that comprise the low structural/non-appearance category, the subsill of the Frenchwood Hinged Door was chosen as the target profile.

The subsill, was formerly a wooden component. It is snap-fit with an aluminum sill cover and its top surface is covered with an oak threshold. In an installed application, the subsill is not visible. It rests on the flooring, so structural stiffness requirements are low. Many times door installations are encountered where the subsill sits directly on a cement grade and so decay concerns for this component are quite high. The oak threshold is fastened to the subsill along its length with screws, applied in a radial direction. This sill assembly is fastened to the sides of the door frame using screws which are driven into the subsill in a longitudinal direction. One last important aspect of the subsill is its compression resistance.

A number of experiments were performed and an optimization of stiffness, moisture absorption, processing and cost brought us to a composition of 40 weight per cent dirty sawdust and 60 weight per cent secondary PVC. These constituents are combined and processed in a proprietary manner to yield a hollow profile. For purposes of this discussion, the resulting material will be called Reclaimed Composite.

Table 1 is a summary of performance testing for the subsill when made out of treated pine (the traditional material) and when made from Reclaimed Composite. Numbers in parentheses indicate the standard deviations of the measurement. The average compression resistance and screw retention in both the longitudinal and radial directions is as high or higher than the wood values we had grown accustomed to in this hinged door product. These values are all highly dependent on the particular profile design utilized. A design tool called finite element analysis was used to optimize these particular strength properties and minimize material usage at the same time. In addition, 500 freeze/thaw and 400 thermal cycles (140°F to -20°F) were performed on the Reclaimed Composite subsill, as assembled into a complete door unit.

Besides the product application testing, a number of material property tests were performed on Reclaimed Composite.
Flexural modulus of 200 samples of Reclaimed Composite indicate an average value of 830,000 psi with a standard deviation of about 25,000 psi. In comparison, 200 samples of Andersen pine cut stock were measured during the summer of 1991 and found to have an average value of 1,000,000 psi, but with a standard deviation of 250,000 psi. The predictable properties of Reclaimed Composite, (as opposed to the variability exhibited by wood) are highly desirable to product designers.

Water absorption of Reclaimed Composite, on a weight gain basis, is approximately 1/7 that of treated pine; fungal decay, as measured by a standard soil block testing is undetectable. The linear coefficient of thermal expansion of Reclaimed Composite is about 1.2 X 10E-5 in/in °F. This is approximately the same value as aluminum (another popular material for window construction). However, the thermal conductivity of Reclaimed Composite is several orders of magnitude less than aluminum.

Andersen implemented its Reclaimed Composite door subsill in February of 1993. During that experience it was learned that the material could be sawed and routed using standard wood-working equipment and tooling. Its use since February of '93 has eliminated the need to buy 7,800 gallons of treating solution that would have been used for the old wood subsill. The purchase of about 400,000 board-feet of lumber has been avoided and about 500,000 lb of dirty sawdust has been saved from landfill.

With a successful introduction of a representative, target profile from the low structural/ non-appearance category, Andersen is pursuing the research needed to manufacture clad or weatherable colored components. In addition, further studies are being conducted by Aspen Research, with funding and application assistance from Andersen, and an additional $100,000 matching grant from the Minnesota Office of Environmental Assistance, in the following areas:

- Further wood fiber/thermoplastic compatibilizers to enhance the strength of such composites.

- Use of non-PVC matrix polymers in combinations with non-wood biofibers.

- The development of non-fenestration applications for these wood fiber-thermoplastic composite technologies.

In summary, the research accomplished through this project has led Andersen to think of wood fiber-thermoplastic composites not simply as a substitute to wood in its products, but as a different and better class of materials for making windows. The implementation of a wood fiber/ thermoplastic composite into Andersen's patio door application has proven that this technology is quite viable for commercial fenestration applications. The product itself is a thermoplastic and thus culled parts and end cuts can be reformed into usable product. The fiber represents a renewable and sustainable resource. The use of waste materials in a commercial application has been demonstrated, and most importantly these waste materials are being utilized in a long life cycle product, as opposed to the recycling of packaging materials where the product life cycle is extremely short.

The economics of a wood fiber thermoplastic composite are very favorable. PVC resin prices may increase, but because that resin is diluted at 40% with a fiber that has almost no value (i.e. sawdust), the cost of a wood fiber-PVC composite is buffered from such increases.

Finally, the development of Reclaimed Composite demonstrates the benefits realized when research, industry, and government work together toward a common goal.

Table 1-Strength Properties of French Wood Hinged Door Subsill

	Perma-Shield II	**Treated Finger-joined Pine**
Compression Resistance, lb	**2309 (35)**	**1980 (760)**
Screw Retention, Longitudinal, lb	**681 (30)**	**613 (49)**
Screw Retention, Radial, lb	**407 (20)**	**86 (69)**

*U.S. GOVERNMENT PRINTING OFFICE: 1995-386-627/37927

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