Shaw Industries: Sustainable Business, Entrepreneurial Innovation, and Green Chemistry[1]

The carpet industry is the battlefield where the war for sustainability is being waged.

— William McDonough, architect and environmentalist

In 2003, Shaw's EcoWorx® carpet tiles won a Presidential Green Chemistry Challenge Award. The company earned the award by applying green chemistry and engineering principles (Exhibit 1) with a cradle-to-cradle design[2] (C2C) approach to create environmentally benign carpet tile, a first in the industry. The product met the rising demand for "sustainable" innovations, helping to create a new market that opened up in the late 1990s and 2000s as buyers became more cognizant of human health and ecosystem hazards associated with interior furnishings and poor indoor air quality.

At the time, Steve Bradfield, Shaw's vice president for environmental development, commented on the process of creating the EcoWorx innovation, a process that was by

[1] The definition of "sustainable business" continues to evolve. For the purposes of this case study, the effort to design "sustainable business" emerged from the scientific recognition that many current business practices undermine ecological systems and human health. Green chemistry (design principles for application at the molecular level) offers a conceptual framework that helps support the co-evolution of economic activity with ecological and human health and stability. See *Green Chemistry: Theory and Practice* by Paul Anastas and John Warner, as well as Anastas, P.; Zimmerman, J. Twelve Principles of Green Engineering. *Environ. Sci. Technol.* 2003, *37*, 94A-101A.

[2] See *Cradle to Cradle* by William McDonough and Michael Braungart (North Point Press: New York, 2002) for extensive discussion of the C2C frame of reference. The field of industrial ecology provides a solid conceptual basis for this discussion. Visit www.mbdc.com (accessed December 28, 2007) for a discussion of the Cradle-to-Cradle Design Protocol.

no means complete: “The 12 Principles and C2C provide a framework for development of EcoWorx that incorporates anticipatory design, resource conservation, and material safety.” The framework was part of a larger sustainability strategic effort to which Shaw was committed. The company also needed to educate the marketplace about the benefits of EcoWorx and other sustainable products, which it considered qualitatively, economically, and environmentally superior replacements for those that had been in place for 30 years. Change was hard, especially when the gains from a substitute product were not well understood by the end-user or the independent distributor.

The U.S. Textile Industry

The World War II demand for wool—then the dominant carpet material, but needed for military uniforms and blankets—provided companies with an incentive to research and create alternative fibers. This move culminated in the introduction of synthetic (man-made) materials for many uses. After the war, manufacturers continued to develop various new natural and synthetic materials. By the 1960s, DuPont and Chemstrand’s man-made nylon and acrylic materials supplied most of the carpeting industry’s textile fiber needs. In 2004, nylon accounted for 68 percent of the fibers used in carpet manufacturing, followed by polypropylene (22 percent) and polyester (9 percent), with wool constituting less than 0.7 percent of the total.

By the 1970s, carpet flooring was the dominant aesthetic standard in a high proportion of the industrialized world’s residential and commercial markets. Historically, carpets were either woven (in which the carpet surface and backing were essentially one layer) or tufted (fibers pulled through a matrix web) and needle-punched and bonded to a backing layer using an array of synthetic fibers and adhesive attachments. Regardless of design, all carpeting is a complex matrix of dissimilar materials. Carpet tiles—the fastest-growing segment of the carpeting industry—was expected to steadily replace the rolled broadloom carpet used in office and other commercial locations.

In 2004, DuPont (10 percent market share), Shaw Industries (6 percent), Milliken & Company (5 percent), Mohawk Industries (5 percent), and Burlington Industries (3 percent) were the top five producers in the fragmented textile market. DuPont, a chemical maker, restructured its businesses and exited the textiles markets. Burlington restructured out of bankruptcy proceedings. Low-priced imports, economic downturn, and overcapacity took a heavy toll on American companies. The industry was consolidating, and companies vertically integrated and formed alliances as lower carpet and floor covering sales tracked personal income insecurity and general economic turbulence. The early 2000s witnessed the loss of more than 90,000 textile jobs and 150 plant closings. The carpets and rugs sector experienced sluggish growth. Growth rebounded by 2005, but competition was fierce and buyers would not tolerate higher prices or lower product performance.

Shaw Industries

In 2005, Shaw Industries of Dalton, Georgia, was the world’s largest carpet manufacturer, selling in North America and exporting worldwide. Historically, the company's primary markets were woven and tufted broadloom carpet. Its carpet brand names included Cabin Crafts, Queen, Designweave, Philadelphia, and ShawMark. The company sold residential products to distributors and retailers and offered commercial products directly to customers through Shaw Contract Flooring. The company also sold laminate, ceramic tile, and hardwood flooring. Shaw Industries was publicly traded on the New York Stock Exchange until 2001, when it was purchased by Warren Buffet's Berkshire Hathaway Inc.

Between 1985 and 2005, Shaw Industries acquired several other large carpet makers, fiber-dying facilities, and yarn mills, moving steadily toward broad vertical integration of inputs and processes:

- *Amoco's polypropylene operations, 1992*: Polypropylene fiber, used mainly in Berber-style residential products, made up approximately 30 percent of the fiber usage in the carpet industry. By purchasing the Amoco plants in Andalusia, Alabama, and Bainbridge, Georgia, Shaw became the world's largest polypropylene producer, extruding all the fiber for its polypropylene carpets. [3]
- *Queen Carpet, 1998*: In October 1998, Shaw purchased the fourth-largest manufacturer of carpets, Queen Carpet, which had $800 million in sales the previous year.
- *The Dixie Group, 2003*: The Dixie Group, one of the nation's biggest manufacturers of carpets for the mobile home and manufactured housing industry, sold six yarn-tufting, dyeing, finishing, and needlebond mills and distribution factories to Shaw for $180 million in October 2003. A carpet recycling facility was included in the sale.

The firm's expensive forays into retail stores ended, but Shaw continued to buy most of its nylon, which accounted for 60 percent of carpet production, from outside fiber producers. Shaw spun, twisted, and heat-set its own yarn and tufted, dyed, and finished the carpet.

Carpet Tile

Carpet tile, as a product category, bridges most commercial market segments (offices, hospitals, universities). On the market for more than 30 years, it was introduced originally as a carpet innovation for low-cost replacement of stained or damaged tiles, rotation of tiles in high-wear zones, and easy access to utility wiring beneath floors. [Carpet tile's unique attributes—higher cost, high mass and embodied energy, more stringent backing adhesion performance specifications compared with broadloom, and double-digit market growth rate—made it a logical focus for exploring alternative tile system designs.]

[3] McDonough.

Carpet tile is comprised of two main elements: the face and the backing. The face is made from yarn made of either nylon 6 or nylon 6,6 fiber, the only viable nylon in commercial carpet. U.S. carpet tile has been made with PVC plastisol backing systems, which provided the tile's mechanical properties and its adhesive stability. PVC was under suspicion, however, due to the potential of the plasticizer to migrate from the material, causing health problems and product failure. Most tufted carpets were made with a layer of PVC backing to provide dimensional stability. Broadloom carpets—primarily sold on rolls and to residential buyers—traditionally had thermostatic PVC backings and thermoplastic PVC was used as the backing for carpet tiles. Shaw stopped using PVC as a backing at the end of 2004.[4]

Backing provides functions that are subject to engineering specifications (such as compatibility with floor adhesives and dimensional stability) and securing the face fibers in place. Selecting backing material and getting the chemistry right for the system's performance took time. Inadequate backing-compound lamination (attachment) was a liability that shortened product service life, reduced tile flexibility (for ease of installation), and reduced wear resistance. To achieve Shaw's performance specifications, Dow Chemical provided new metallocene polyolefin polymers, to which Shaw added a proprietary compounding process to complete the material design. Seeking every possible way to reduce materials use, remove hazardous inputs, and yet maintain or improve product performance, Shaw made the following changes:

- Replacement of PVC and phthalate plasticizer with an inert and non-hazardous mix of polymers, ensuring material safety throughout the system (PVC-contaminated nylon facing cannot be used for non-carpet applications of recycled materials).
- Elimination of antimony trioxide flame retardant, which has been associated with harm to aquatic organisms.
- Dramatic waste reduction during the processing phases by immediate recovery and use of the technical nutrients (the production waste goal is zero).
- A life-cycle inventory and mass flow analysis that capture systems impacts and material efficiencies compared with PVC backing.
- Efficiencies (energy and material reductions) in production, packaging, and distribution—for example, EcoWorx tiles are 40 percent lighter than PVC-backed tiles, saving on transport and handling (installation and removal/demolition).
- Minimizing the number of raw materials and selecting those that do not lose value and can be continuously disassembled and remanufactured.

[4] National Floor Trends. http://www.ntlfloortrends.com/Articles/Breaking_News/56fae56ad01b7010VgnVCM100000f932a8c0 (accessed March 5, 2009).

- Use of closed-loop, integrated, plant-wide cooling water system that provides chilled water for the extrusion process as well as the heating and cooling systems (HVAC).
- Labels on every EcoWorx carpet tile that direct the buyer to call a toll-free number to request removal of the material for recycling].

While Shaw had not begun to get carpet tiles back for recycling, models assessing comparative costs of the conventional feedstock versus the new system indicated the recycled components would be less costly to process than virgin materials

EcoWorx Innovation

The EcoWorx system developed by Shaw Industries offered a way to analyze and refine the cradle-to-cradle (C2C) design of a carpet tile system without regard to technology constraints of the past. The Twelve Principles of Green Engineering and C2C provide a detailed framework in which to evaluate a new technology for engineering a successful carpet tile production, use, and recovery system. The EcoWorx system also utilizes Shaw's EcoSolution Q nylon-6 premium-branded fiber system, which is designed to use recycled nylon-6 and currently embodies 25 percent postindustrial recycled content in its makeup. A third party, McDonough Braungart Design Chemistry (MBDC), validated the minimum 25 percent recycled content claim. And, the EcoSolution Q nylon-6 branded fiber system could be recycled as a technical nutrient through a reciprocal recovery agreement with Honeywell's Arnprior depolymerization facility in Canada without sacrificing performance or quality or increasing cost. This arrangement allows Shaw's carpet tile products to make a C2C return to manufacturing, with backing and fiber from tile made into more backing and fiber.

Shaw's objective was to create technology for an infinitely recyclable carpet tile, one that could be entirely recycled with no loss in quality from one life cycle to the next. The notion of closed-cycle carpet tiles forced the complex issue of compatibility between face fiber (the soft side on which you walk) and the backing. Shaw chose nylon-6 for the face fiber because it is the only material that could be reprocessed. The nylon-6 material also retains its flexibility and structure through multiple reprocessing cycles. Furthermore, unlike that of nylon-6,6, nylon-6 recycling facilities had sufficient capacity to support a large increase in incoming stock. Shaw then began to explore various resins, searching for a tile backing that could compare in performance to PVC and also recycle congruously with nylon-6.

In 1997, a Shaw researcher remembered reading about a particular method of processing polyolefin resins that produced flexible, recyclable polymers. Polyolefins were an intriguing material for Shaw to explore as carpet backing, since its purchase of Amoco polypropylene (a type of polyolefin) extrusion facilities gave it 300 million pounds of fiber extrusion capacity. After Shaw invested nearly $1 million in research and development, tests suggested that polyolefins could be melted and separated from nylon-6 and, therefore, successfully recycled into like-new materials. Shaw created a pilot line of carpet tile set on a polyolefin backing that exceeded the performance of traditional PVC backings. This experiment was the start of EcoWorx.

Shaw first introduced EcoWorx commercially in 1999. As a polyolefin-backed carpet tile, EcoWorx offered an alternative to the industry-standard PVC backing at comparable cost, 40 percent less weight, and equal or improved effectiveness across all performance categories. EcoWorx earned the 1999 Best of Neocon Gold Award at the prestigious and largest annual interior furnishings and systems show in the United States. In 2002, the company's EcoWorx tile called "Dressed to Kill" won the Neocon Gold Award for carpet tile design, effectively mainstreaming the new material. Indeed, customers preferred the new product and, consequently, by 2004, 80 percent of carpet tile sold by Shaw—faster growth than anticipated—was made with EcoWorx. Shaw soon announced that EcoWorx would be the standard backing for all of its new carpet tile.

EcoWorx as a system of materials and processes proved significantly more efficient. The backing is dramatically lighter compared with PVC-backed tiles. The extrusion process, which uses electric coating stations rather than a traditional gas-fired or forced-air oven, is more energy efficient. The process combines an ethylene polymer base resin (developed by Dow Chemical) with high-density polyethylene (HDPE), fly ash for bulk (instead of the virgin calcium carbonate traditionally used), oil to improve the product's compatibility with the floor glue, antimicrobial substances, and black pigment. This compound is applied to carpet backs using a low-odor adhesive to maintain high indoor air quality standards. The backing material is often combined with a non-woven fiberglass mat for stability. The chemistry was designed to be compatible not only with recovered EcoWorx backing, but also with other recycled polymer streams that might become available going forward.[5]

Shaw and the customer agreed, at the point of sale, that the manufacturer would pay to have the carpet returned to it. Back in its plant, Shaw would shred it and separate the backing stream from the fiber stream. The "infinitely recyclable" duo of Shaw's nylon-6 fibers (marketed as Eco-Solution-Q) and EcoWorx backing received acclaim throughout the industry. Their competitive cost and exceptional performance compared to traditional products allowed them to step beyond the limits of the "green" niche market. Especially important, Shaw's research showed that the cost of collection, transportation, elutriation,[6] and reprocessing was less than the cost of using virgin raw materials.[7] Shaw tripled its production capacity in 2000 and, by the end of 2002, shipments of EcoWorx tiles exceeded PVC-backed styles.[8] Shaw continued to expand collection and

[5] *EcoWorx Carpet Tile: A Cradle-To-Cradle Product.* Green Chemistry Application, 2003.

[6] Elutriation refers to the process of shredding returned tiles and their purification by washing, straining, or separating by weight.

[7] *EcoWorx Carpet Tile.*

[8] *Ibid.*

recycling capacity in preparation for 2007, when the first round of EcoWorx carpet that was released in 1999 would reach the end of its *first* life cycle. It appeared that Shaw would be the first to close the industrial loop in the carpet tile industry.

The Recycling Challenge — Fits and Starts

Recycling carpet is a complex endeavor, as carpet is composed of layers of face fibers, glues, fillers, stabilizers, and backings, each with varying capacity to be melted and reused. Approximately 68 percent of the face fiber used in carpets is made of either nylon-6 or nylon-6,6, with each of these two types comprising an equal portion of the nylon carpet fiber market. Nylon-6 and nylon-6,6 are roughly even in carpet market share. Neither fiber has the production capacity to serve the entire carpet industry.

Both nylons make excellent carpet. While recovered nylon-6,6 can be recycled into other, non-carpet materials, such as car parts and highway guardrails, the economic incentives for companies were low and it was argued that “downcycling” in this way only postponed discarding the product in a landfill by one life cycle.

DuPont and Solutia, the only producers of nylon-6,6, have a long history of technical development and response to competitive challenges. Promising work is now underway in dissolution technologies that would allow post-consumer nylon-6,6 to be recycled in an economical manner, restoring the uneasy balance between the two nylon types on the environmental front. Nylon-6,6 is here to stay. Industry observers said large-scale recycling of nylon-6,6 is a matter of when, not if, the process is perfected.

In contrast, the technology to recycle nylon-6 fibers back into new carpet face fiber was developed and Honeywell International Inc., a major supplier of the nylon-6 fiber used by carpet manufacturers, was so confident about the market potential for renewed nylon-6 fiber that it developed an $80 million recycling facility in Augusta, Georgia. Unfortunately, the cost of reclaimed nylon-6 was not competitive with virgin nylon-6 at that time, forcing the plant to close in 2001.[9]

The Honeywell Evergreen nylon-6 depolymerization unit was expected to restart and the technology undoubtedly would be improved. But the combined depolymerization capacities of Evergreen, Honeywell/BASF, and Polyamide 2000 were very small for the foreseeable future.

Environmental and Health Concerns Associated with Carpeting

Post-World War II, the design and manufacture of products from man-made and naturally occurring chemicals provided a wide range of inexpensive, convenient, and

[9] Salant, K. Carpet Industry Makes Strides in Reducing Footprint, but Path Includes Several Obstacles. *The Washington Post.* January 31, 2004, p F5.

dependable consumer goods on which an increasing number of people relied worldwide. Behind the valuable medicines, plastics, fuels, fertilizers, and fabrics lay new chemicals and processes that were not time-tested, but appeared to have superior performance relative to prewar materials. Most of the polymer building blocks developed by chemists between 1950 and 2000 resulted from the post-World War II economic boom.

By the 1990s, the growing rate of carpet usage led to serious concern over waste disposal. Ninety-five percent of carpet ended up in landfills. In 2002, 4.7 billion pounds of carpet entered the U.S. waste stream.[10] In response to growing water quality, cost, and land-use issues, government and commercial buyers pressured manufacturers to develop carpet recycling technologies. In January 2002, carpet and fiber manufacturers signed the National Carpet Recycling Agreement together with the Carpet and Rug Institute (the industry trade association), state governments, non-governmental organizations, and the U.S. Environmental Protection Agency (EPA). This voluntary agreement established a 10-year schedule to increase recycling and reuse of post-consumer carpet and reduce the amount of waste carpet going to landfills. The agreement set a national goal of diverting 40 percent of end-of-life carpet from landfill disposal by 2012. Responding to this pressure in 2002, industry representatives also created the Carpet America Recovery Effort (CARE), a partnership of industry leaders designed to enhance the collection infrastructure for post-consumer carpet and report on the carpet industry's progress toward meeting the national goals defined in the Memorandum of Understanding for Carpet Stewardship (MOU).[11] In the late 1990s, Presidential Executive Order 13101, a purchasing guide, fueled demand for "environmentally preferable products" by the U.S. government and purchasers who received federal funds.

But the problems with carpeting would not be addressed so easily. As monitoring equipment capabilities advanced between 1990 and 2005, new health and ecological impact hazards associated with certain widely used chemicals were identified. Concern about the "environment"—a topic historically related to on-site toxins and compliance activity and relegated to the corporate Environment, Health, and Safety office—became a health matter *after* the product left the company. Scientists, design engineers, and increasingly middle- and senior-management needed to incorporate this understanding into the ways products were designed and made. This was particularly true in the construction and home furnishing sectors, where greater use of chemicals, combined with less-than-adequate ventilation and more architecturally tight building designs, create health problems.

As far back as 1987, the U.S. Consumer Product Safety Commission (CPSC), the federal agency that monitors commercial product safety, received more than 130

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[10] U.S. Environmental Protection Agency (EPA) Carpet. Product Stewardship Fact Sheet. http://www.epa.gov/epawaste/partnerships/stewardship/products/carpet.htm (accessed March 5, 2009).

[11] Carpet America Recovery Effort, 2004. http://www.carpetrecovery.org/mou.php (accessed March 5, 2009).

complaints about flu and allergy symptoms and eye/throat irritations that began after the installation of new carpet. Although a small number of incidents, this data often represented the tip of a health-problem iceberg. Over the next few years, air quality research led to the well-publicized concept of "sick building syndrome"—a condition in which occupants experience acute health and comfort effects linked to poor indoor air quality. Carpets were not the only culprits. Wall materials and wall coverings (paint and wallpaper), as well as various hardwood floor treatments, also were implicated. To the industry's dismay, the U.S. EPA listed "chemical contaminants from indoor sources, including adhesives [and] carpeting … that may emit volatile organic compounds (VOCs)" as contributors to sick building syndrome.[12] Of course, the building was not sick. At the time, the U.S. Centers for Disease Control reported "body burdens" of chemicals in people's bloodstreams from unidentified sources. Under increasing study were babies' body burdens—the pollutants in infants' blood and organ tissues—later known to result from placental cycling of blood, oxygen, and nutrients between mother and child.

Simultaneously, concern built throughout the 1990s concerning PVC plastic that contained phthalate plasticizers. Phthalates are added to PVC during processing to make the resulting plastic soft and flexible. Scientists found phthalate molecules did not structurally bind to PVC, however, and leached out of products. Though the level of harm to humans was debatable, reputable studies linked phthalates to reproductive and endocrine disorders in animals. Environmental health science reports and concerns over PVC plasticizers grew steadily between 1995 and 2005. California planned to add DEHP, a type of phthalate, to a list of chemicals known to cause birth defects or reproductive harm. The list, contained in Proposition 65, followed on the heels of warnings from the U.S. Food and Drug Administration, the National Toxicology Program, and Health Canada that DEHP may cause birth defects and other reproductive harm. Furthermore, incineration (burning at high temperatures) of PVC released highly toxic organochlorine byproducts, including microscopic dioxins, into the atmosphere, where they moved with regional weather patterns, returning to the lower atmosphere and eventually to Earth through the hydrologic cycle. Laboratory and production worker data indicated that breathing dioxins were linked to cancer, growth disruptions, and developmental problems in humans. By July 2005, links between commonly used chemicals, even in very low doses, and human health deficiencies were being discussed on the front page of the *Wall Street Journal*.[13]

Shaw Focuses on Carpet Tile

For Shaw, the obvious place to start was at the top of the carpet hierarchy, carpet tile. Its high price compared to broadloom carpets, thermoplastic PVC plastisol backing, and

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[12] U.S. Environmental Protection Agency (EPA) Indoor Air Facts No. 4 (revised) Sick Building Syndrome. http://www.epa.gov/iaq/pubs/sbs.html (accessed Jun 24, 2004).

[13] Waldman, P. Common Industrial Chemicals in Tiny Doses Raise Health Issue. *Wall Street Journal*. July 25, 2005.

relative ease of recovery from commercial buildings, where large volumes of product could be found, seemed the best hope for early success. That may have been the first and last point of agreement among fiber and carpet manufacturers as sustainability began to take on widely differing meanings. Specifiers and end-users comparing the environmental impacts of competitive carpet tiles often were confused by the lack of standards defining and measuring sustainability.

Many carpet manufacturers focused their early environmental efforts on reducing trim waste from industrial and installation processes (eco-efficiency). Trim waste cost the industry an estimated $25 million per year in unused carpet production and disposal fees, but this represented only 2 percent of total carpet production and, while important, made a relatively small impact on the end-of-life waste volume issue. As efficiency strategies became more systems oriented, a competitive market grew for technology to recover and recycle post-consumer carpet.

In fact, for many years, real solutions to the problems of end-of-life recycling of carpet were lost in the clutter of the first and easiest step in environmental stewardship—reduction of materials, water, energy usage, and waste. Capabilities were developed, typically under a company's Environment, Health, and Safety office (EH&S), that essentially absorbed quality and cost-cutting issues under the compliance function. With respect to carpeting materials, efforts were concentrated on the 2 percent of all carpet materials that remained as scrap in the manufacturing plants. More than 98 percent of all materials entering the carpet-manufacturing stream were shipped to the customer as finished carpet. Once used and in need of replacement, this post-consumer carpet traditionally ended its life in landfills.

Other environmental efforts in the carpet industry focused on converting or recycling products like PET plastic bottles (waste streams from other industries) into carpet fiber, incorporating the recovered materials into new products. The Comprehensive Procurement Guideline (CPG) program[14] (Executive Order 13101, 1998) mentioned earlier, encouraged this effort. Of the items listed in the program, PET and nylon carpet face fiber, carpet backing, and carpet cushioning were included. The U.S. EPA gave priority to products containing a high percentage of post-consumer material. Because Shaw EcoWorx—a breakthrough product designed for 100 percent recovery—had not been fully executed, it was not included on the vendor list.

In 2005, recycled plastic remained more costly than virgin fibers, thus limiting the carpet industry's enthusiasm for this measure. But plastic came from oil, a feedstock source increasingly subject to price volatility and unstable supply. In 2004, oil prices hit a 13-year high at $60 billion and exceeded that figure by mid-2006. In the face of this price uncertainty and consistently high oil prices, Shaw concentrated on, and eventually achieved, systems economics that resulted in the recovered EcoWorx materials coming back as feedstock under the price of virgin materials.

[14] U.S. Environmental Protection Agency (EPA). http://www.epa.gov/cpg/about.htm (accessed June 24, 2004).

Green Building Council and LEED

Steve Bradfield, a pioneer in the founding of the U.S Green Building Council's Leadership in Energy and Environmental Design (LEED) program—which established standards for environmentally preferred building materials and construction—had participated for several years in the architecture and building industries' movement to reduce and eliminate problematic materials that were increasingly linked with respiratory, allergy, and other human health problems. In 2003, Bradfield talked about Shaw's sustainability policy (the following year, he would testify before Congress in support of green legislation; see Exhibit 2). Shaw's policy, Bradfield explained, articulated the firm's corporate strategy to move steadily toward a cradle-to-cradle and solar-powered future:

> As we learn and grow, this policy will be refined by generations of Shaw leaders who won't think about sustainability. They'll see it as an essential business practice, perhaps without realizing that previous generations consciously changed direction to use sustainability principles for competitive advantage and to better the world in which they lived.

LEED requirements incorporated points—reflected in EcoWorx recovery and reuse benefits—that could be earned by companies to achieve higher LEED rankings. Top LEED certification levels for headquarters buildings were important goals for many corporations committed to sustainability practices, or at least those wanting to gain positive publicity for their efforts.

Environmental pressure had been building for several years in the carpet industry. Said William McDonough, architect, environmentalist, and promoter of the C2C design approach with Michael Braungart: "The carpet industry is the battlefield where the war for sustainability is being waged." Indeed, so many carpet companies seemed to be actively marketing sustainable carpet compared to other industries that the question, "why carpet?" is often asked. With Presidential Executive Order 13101 and other mandates fueling the demand for "environmentally preferable products" in government, a new breed of environmentalist appeared by the late 1990s, ready to constructively engage in a dialogue with industry.

The first LEED Green Building Rating System™ was completed in 2000 and grew quickly into an internationally recognized certification program for environmentally sensitive design.[15] Recognizing that buildings account for 30 percent of raw materials use and 30 percent of waste output (136 million tons annually) in the United States,[16]

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[15] U.S. Green Building Council, LEED Rating Systems. http://www.usgbc.org/DisplayPage.aspx?CMSPageID=222 (accessed March 6, 2009).

[16] U.S. Environmental Protection Agency (EPA). *Characterization of Building-Related Construction and Demolition Debris in the United States*. http://www.owr.ehnr.state.nc.us/ref/02/01095.pdf (accessed March 6, 2009).

the U.S. Green Building Council, an organization affiliated with the American Association of Architects, drew together representatives from all sectors of the building industry to develop this voluntary and consensus-based rating system.[17] By adhering to an extensive point system—with categories such as indoor environmental quality, materials and resources, and water efficiency—both new buildings and interior renovations could become LEED-certified at different levels of excellence (silver, gold, and platinum). Carpet selection became an integral element of LEED certification through materials requirements, such as "minimum recycled content" and "low-emitting adhesives and carpeting."[18]

As of March 2009, the LEED Green Building Rating System had more than 18,800 member organizations and certified projects in all 50 states and 91 countries.[19].LEED's continued influence in the building industry was secured by myriad U.S. governmental agency policies[20] mandating differing levels of LEED standards for future buildings. By 2005, California, Maine, Maryland, New Jersey, New York, Oregon, and many American cities also legislated LEED standards for construction and procurement at various levels, either through mandates on capital developments or tax credits to developers who met the requirements.[21]

Certifiers

Third-party organizations, both for-profit and not-for-profit, proliferated in 2005 and 2006 in a bid to gather the critical mass necessary to be recognized as the certifier of choice for many different aspects of the environmental patchwork of metrics defining that elusive goal called sustainability. Various industry associations attempted to build consensus by developing self-certification programs. Recycled content seemed to be the path of least resistance, but life-cycle analysis, embodied energy studies, and variations on the complex theme of "closing the loop" proliferated and jockeyed for position in the new "industry" of environmental and health performance. Unfortunately, an inevitable "unintended consequence" of these efforts was confusion and controversy among stakeholders.

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[17]U.S. Green Building Council, Leadership in Environmental and Energy Design. http://www.usgbc.org/LEED/LEED_main.asp (accessed Jun 24, 2004).

[18] *Ibid.*

[19] U.S. Green Building Council, Green Building Facts. http://www.usgbc.org/ShowFile.aspx?DocumentID=3340 (accessed March 6, 2009).

[20] These agencies included the U.S. EPA, the General Services Administration, the Department of State, and three branches of the U.S. military.

[21] U.S. Green Building Council, Summary of Government LEED Incentives – July 2008 http://www.usgbc.org/ShowFile.aspx?DocumentID=2021 (accessed March 6, 2009).

Entrepreneurial Initiative: Interface

The most significant leap toward sustainability in the carpet industry began in 1994, when Interface, Inc., led by owner Ray Anderson, adopted a radical and comprehensive strategy that served to “green” the company from top to bottom. This was no small feat, given that Interface had invented carpet tile and was a billion-dollar company that produced 40 percent of the world’s commercial tile.[22] Since 1994, Interface has saved $222 million by reducing scrap waste, identifying operational inefficiencies, and lowering energy needs by using less nylon in carpet tiles.[23]

The company introduced carpet-leasing programs in which it collected and recycled end-of-use carpet. Interface converted one of its plants to solar energy and explored other renewable energy and energy efficiency measures across its U.S. facilities. According to Anderson, “Sustainability is proving to be incredibly good for business. What began as the right thing to do quickly become the smart thing to do. Sustainability doesn’t cost, it pays.”[24] By raising the bar for innovation in a sector with such wide health and environmental impact, Interface helped draw its competitors, which included the largest carpet manufacturers in the world, into a race toward sustainability.

What Next?

As Steve Bradfield reflected on the next few years’ challenges, he hoped the innovations required to implement the EcoWorx strategy were within the capabilities of Shaw and its partner firms. Questions went through his mind: Did the company fully understand reverse logistics systems design? Had it identified the probable challenges and bottlenecks? Was everyone necessary on board to execute the strategy successfully? Would Shaw have sufficient capacity for the disassembly stage? The capacity of the elutriation system initially would allow Shaw to recycle 1.8 million square yards of carpet per year. This equipment enabled separation of the backing and fiber in a single pass and was expected to meet the anticipated increase in returned post-consumer material over the next five to ten years. But how would the company calculate the economics of the system to understand whether it was successful or not?

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[22] Anderson, R. Climbing Mount Sustainability. *Quality Progress. 2004,* 37, 2.

[23] *Ibid.*

[24] *Ibid.*

Exhibit 1

The 12 Principles of Green Chemistry and Green Engineering

Green Chemistry

1. **Prevention.** It is better to prevent waste than to treat or clean up waste after it has been created.
2. **Atom Economy.** Synthetic methods should be designed to maximize the incorporation of all materials used in the process into the final product.
3. **Less Hazardous Chemical Syntheses.** Wherever practicable, synthetic methods should be designed to use and generate substances that possess little or no toxicity to human health and the environment.
4. **Designing Safer Chemicals.** Chemical products should be designed to effect their desired function while minimizing their toxicity.
5. **Safer Solvents and Auxiliaries.** The use of auxiliary substances (e.g., solvents, separation agents, etc.) should be made unnecessary wherever possible and innocuous when used.
6. **Design for Energy Efficiency.** Energy requirements of chemical processes should be recognized for their environmental and economic impacts and should be minimized. If possible, synthetic methods should be conducted at ambient temperature and pressure.
7. **Use of Renewable Feedstocks.** A raw material or feedstock should be renewable rather than depleting whenever technically and economically practicable.
8. **Reduce Derivatives.** Unnecessary derivatization (use of blocking groups, protection/deprotection, temporary modification of physical/chemical processes) should be minimized or avoided if possible, because such steps require additional reagents and can generate waste.
9. **Catalysis.** Catalytic reagents (as selective as possible) are superior to stoichiometric reagents.
10. **Design for Degradation.** Chemical products should be designed so that at the end of their function they break down into innocuous degradation products and do not persist in the environment.
11. **Real-Time Analysis for Pollution Prevention.** Analytical methodologies need to be further developed to allow for real-time, in-process monitoring and control prior to the formation of hazardous substances.
12. **Inherently Safer Chemistry for Accident Prevention.** Substances and the form of a substance used in a chemical process should be chosen to minimize the potential for chemical accidents, including releases, explosions, and fires.

Green Engineering

1. **Inherent Rather Than Circumstantial.** Designers need to strive to ensure that all materials and energy inputs and outputs are as inherently nonhazardous as possible.
2. **Prevention Instead of Treatment.** It is better to prevent waste than to treat or clean up waste after it is formed.
3. **Design for Separation.** Separation and purification operations should be designed to minimize energy consumption and materials use.
4. **Maximize Efficiency.** Products, processes, and systems should be designed to maximize mass, energy, space, and time efficiency.
5. **Output-Pulled Versus Input-Pushed.** Products, processes, and systems should be “output pulled” rather than “input pushed” through the use of energy and materials.
6. **Conserve Complexity.** Embedded entropy and complexity must be viewed as an investment when making design choices on recycle, reuse, or beneficial disposition.
7. **Durability Rather Than Immortality.** Targeted durability, not immortality, should be a design goal.
8. **Meet Need, Minimize Excess.** Design for unnecessary capacity or capability (e.g., “one size fits all”) solutions should be considered a design flaw.
9. **Minimize Material Diversity.** Material diversity in multi-component products should be minimized to promote disassembly and value retention.
10. **Integrate Material and Energy Flows.** Design of products, processes, and systems must include integration and interconnectivity with available energy and materials flows.
11. **Design for Commercial “Afterlife.”** Products, processes, and systems should be designed for performance in a commercial “afterlife.”
12. **Renewable Rather Than Depleting.** Material and energy inputs should be renewable rather than depleting.

Sources: Anastas, P.; Warner, J. *Green Chemistry: Theory and Practice*. Oxford University Press: New York, 1998, 30; and Anastas, P.; Zimmerman, J. Design through the 12 Principles of Green Engineering. *Environ. Sci. Technol.* 2003, *37*, 95-101. Used by permission.

Exhibit 2

The Green Chemistry Research and Development Act of 2004
House Committee on Science Hearing, March 17, 2004

Steve Bradfield, Vice President for Environmental Development, Shaw Industries, Representing the Carpet and Rug Institute[25]
(Excerpt)

Imagine a future when no carpet goes to a landfill but is separated into its constituent parts at the end of its useful life to be sustainably recycled over and over again. This is happening today with some carpet types, but not enough as yet to significantly divert the 4.5 billion pounds of carpet that went to our nation's landfills in 2003. *Green chemistry can help to develop beneficial uses for the materials used to make carpet today and assure that steady progress is made toward sustainable materials that can go directly back into carpet production in the future.*

Perhaps the most compelling reason to support green chemistry and the growth of sustainable materials and processes in carpet is jobs. Annual carpet production and consumption in the U.S. of $12 billion is equal to the rest of world carpet production and consumption combined. Carpet jobs will stay in the U.S. if we can develop ways to keep post-consumer carpet materials in sustainable closed-loop recycling systems that reduce the need for virgin raw materials and lower the energy embodied in successive generations of carpet products. *Why would any U.S. company choose to manufacture overseas if their valuable raw materials are being collected and recycled at lower cost, with no sacrifice of performance, from American homes and businesses in close proximity to the means of production?*

The economic benefits of green chemistry are quantifiable in each of the examples given herein. As an industry, green chemistry has helped to reduce the water required for dyeing a square yard of carpet from 14.9 gallons in 1995 to 8.9 gallons in 2002. The energy required from thermal fuels to make a square yard of carpet has fallen from 14.5 million BTUs in 1995 to 10.3 million BTUs in 2002. Today the carpet industry has the same level of CO_2 emissions it reported in 1990, yet it produces 40 percent more carpet.

Shaw's experience with green chemistry is representative of the developments that are ongoing in the industry. By way of illustration, Shaw's polyolefin carpet tile backing has fueled an average annual growth rate in carpet tile of almost 15 percent per year over the last four years. This growth provides 440 jobs in our Cartersville, Georgia, carpet tile facility and generates more than $100 million in revenue. It has reduced packaging costs by 70 percent, shipping costs by 20 percent, and resulted in more than $100,000 in annual postindustrial scrap recovery. The recovery of the post-consumer carpet tile

[25] Bradfield full statement. http://positiontoknow.com/S-11/doc/www.house.gov/science/hearings/full04/mar17/bradfield.pdf (accessed March 6, 2009).

will result in even more second-generation savings. *Other manufacturers can share economic success stories that are just as compelling.*

In 1950, the carpet industry shipped 97 million square yards of carpet. In 2001, we shipped 1.879 billion square yards. Between 1965 and 2001, carpet increased in price by 90.4 percent, while the same time period saw an automobile increase 180.4 percent and a combined total of all commodities increased 315.4 percent. More than 80 percent of the U.S. carpet market is supplied by mills located within a 65-mile radius of Dalton, Georgia. *Carpet is important to the economy of Georgia and the United States. Green chemistry is an important tool to facilitate its continued growth.*

In conclusion, we support the adoption of the *Green Chemistry Research and Development Act of 2004* with the suggestions that Congress encourage a cooperative effort among government, academia, and business; that Congress seek additional incentives to reward those companies that commercialize green chemistry developments; that obstacles to the green chemistry discovery process be removed from current federal environmental programs; and that adoption of green chemistry in the broader context of sustainable product development should become a primary instrument of pollution prevention policy in the United States with the additional goals of job creation and economic improvement.