Design Futures Council

Challenge and Context

Paradoxes in Vinyl and Sustainable Design

Counsel House Research/The Greenway Group

Focus on the Future

Vinyl, or PVC, has both supporters and foes, including the most informed experts on green and sustainable design. Perhaps there is more "paradox" associated with vinyl than with any other building material today.

Green building is often defined as a practice that reduces building impact on the environment and on human health and increases the efficient use of energy, water and materials by buildings and construction sites. The practice must run through the complete building cycle: site selection, design, construction, operation and removal.

Many organizations and government agencies have concentrated efforts on sustainability, defined by some as meeting the needs of the current generation without sacrificing the resources of future generations. The 1992 AIA *Environment Resource Guide* became a key document in encouraging building product manufacturers to move toward sustainability by development and use of ecologically-sensitive products. The standards and measuring instruments created are still under debate and revision. Conferences on sustainable design and construction are common. All have implications for architects, engineers, designers and manufacturers of building materials.

As a result, construction materials are under scrutiny. And often products that are not "natural" are viewed with the most criticism. Vinyl, or PVC, has both supporters and foes, including the most expert and informed experts on green and sustainable design. Perhaps there is more "paradox" associated with vinyl than with any other building material today. Its manufacturers often seem in a defensive mode.

Much of the controversy around vinyl stems from concerns related to its production and disposal, and its effect on workers, communities and the environment.

DesignIntelligence
KNOWLEDGE REPORTS
AUGUST 2004

However, vinyl is generally well-regarded for its performance as a low-cost, durable, easy-to-maintain material. Many institutions, organizations and professional firms say the only way to reconcile the pros and cons of any material, product or system is to evaluate them through life-cycle analysis, which reviews energy, environmental and health impacts from the extraction of raw materials through manufacturing, processing, distribution, use and maintenance to end-of-life disposition.

LCAs show that the issues related to vinyl are not particularly unique and that energy and environmental benefits can offset its deficits.

This study looks at some of the most current information on issues associated with vinyl. It also looks at vinyl's future from the perspective of some "green" and sustainable design thought leaders.

Life-Cycle Analysis shows that the issues related to vinyl are not particularly unique and that energy and environmental benefits can offset its deficits.

Vinyl: Production to End-of-Life

Vinyl starts with two simple elements: chlorine (57 percent), based on common salt, an inexpensive, renewable resource; and ethylene (43 percent) from non-renewable fossil fuel, usually natural gas. To our knowledge, renewable fuel sources such as plant oils are not currently used to make vinyl, although experts suggest that could be a future possibility.

Through chemical reaction, ethylene and chlorine combine to form ethylene dichloride, which is then transformed into a gas called vinyl chloride monomer (VCM). A step called "polymerization" converts that into a fine-grained, white powder or resin, known as polyvinyl chloride (PVC or vinyl). The issues, as we seem them are:

Health, Safety during Manufacturing—With some 3,500 people employed in the vinyl resin industry—many in plants—protecting workers and the communities near production facilities is an issue. Worker safety is also an issue in fabricating plants, where as many as 100,000 or more are involved in extrusion, molding, calendaring and other processes to make vinyl products for building, medicine, automobiles, electronics, consumer and other products. Vinyl production facilities are regulated by the U.S. Occupational Safety and Health Administration, and all emissions are regulated by the U.S. Environmental Protection Agency and reported under state and federal law.

Vinyl Chloride Monomer (VCM)—Worker exposure to vinyl chloride monomer (VCM) was a concern in the late 1970s, when workers in vinyl polymerization plants who were exposed to prolonged, high amounts of vinyl chloride monomer were at risk for developing angiosarcoma of the liver, a rare form of cancer. Tighter limits on workplace exposure and changes throughout the vinyl manufacturing industry that involved switching to an enclosed process (both implemented in the 1970s) have virtually eliminated this risk (*Morbidity and Mortality Weekly Report*, 1997). According to industry, there has been no proof of any workers

contracting angiosarcoma of the liver who began employment in the vinyl industry after the regulatory and manufacturing changes were made.

According to EPA estimates, VCM emissions have been reduced by more than 99 percent since the 1970s. Based on 200,000 employee hours, the U.S. Bureau of Labor Statistics reports that the work-related injury and illness incident rate in vinyl resin manufacturing plants dropped from 3.95 in 1994 to 1.14 in 2001. That rate is lower than for the overall chemical industry and far below the rate for all manufacturing.

With the majority of U.S. vinyl production located in Louisiana, critics often point to plant emissions affecting nearby residents. However, a 2002 report from the Louisiana Department of Health and Hospitals found that the overall cancer rate in those areas was in line with the national and statewide cancer rates. Again, industry says no evidence exists that a member of the general population has been harmed by VCM exposure.

Once VCM is converted to PVC, or vinyl, it becomes virtually inert and cannot convert back to its former state.

A 2002 HBO documentary, *Blue Vinyl*, gained some visibility raising concerns over PVC hazards associated with workplace and community exposure, but the film appears to be short on practices and facts in today's production and use of vinyl.

Dioxin —Current studies we reviewed state that vinyl production is a small contributor of dioxin—although this fear is often discussed by opponents of vinyl. A vinyl industry study for 1995 suggested that the industry's dioxin emissions were about 12.6 grams or less than one-half of one percent of the total dioxin emissions to air, water and land reported by EPA for that year. In the past 30 years, production of vinyl has more than tripled, yet dioxin levels in the environment have steadily declined, according to EPA data. Explanations for the decreases include improved waste incineration, phase-out of leaded gasoline, advances in emissions controls, prohibition on open burning, changes in pulp and paper bleaching and other factors.

Additives—Vinyl, like many other materials, uses additives such as stabilizers and plasticizers for performance. Stabilizers aid manufacturing and make products durable but are only a small, tightly-regulated portion of product (less than 5 percent). Plasticizers, used in flexible vinyl products, may account for more than 50 percent of the product. One class of plasticizer, phthalates, is commonly used in building products. They are also accepted for use in medical products regulated by the Food and Drug Administration and in a variety of other consumer and specialty products. The Consumer Products Safety Commission thoroughly reviewed the use of phthalates in toys and found no cause for concern.

Statistics report that the work-related injury and illness incident rate in vinyl resin manufacturing plants dropped from 3.95 in 1994 to 1.14 in 2001. That rate is lower than for the overall chemical industry and far below the rate for all manufacturing.

Vinyl roofs often carry the ENERGYSTAR® designation—because the roof reflects at least 65 percent of the sun's rays.

Transportation—Vinyl is lighter than most other building materials, therefore reducing fuel used for transportation. Light weight also makes it a preferred product for contractors and sub-contractors.

Durability—Most vinyl is strong, durable and moisture-resistant; it withstands rust and corrosion. After a 6.7-magnitude California earthquake, PVC main lines remained in service while asbestos, cement and steel pipes experienced hundreds of breaks.

Fire Safety —Rigid vinyl is inherently flame-retardant due to its chlorine base. Generally, it does not readily ignite or continue to burn once a flame or heat source is removed. Vinyl conduit will not arc or short as metal tubing can, and in this regard offers a reduced fire threat in electrical applications. Flexible vinyl products contain plasticizers, which are flammable, but they are likely also to contain flame retardants or non-combustible additives and fillers (such as calcium carbonate used in flooring). Like all carbon-based materials, vinyl will burn when exposed to certain conditions and should be installed according to local building codes. Products of vinyl combustion appear to be no more hazardous than those produced by many other common materials, both natural and synthetic. The one unique byproduct of burning vinyl, hydrogen chloride (HCl), has about the same toxicity as carbon monoxide, which is produced by anything that burns, but its toxicity is less of a concern than that of CO in a fire because HCl decays by reacting with most construction surfaces. CO, odorless and released by anything that burns, is recognized as the greatest fire hazard.

Energy use in Manufacturing—A study by Franklin Associates conducted for the plastics industry compared the amount of energy consumed in manufacturing equivalent units of product between vinyl and competing materials. The findings: concrete pressure pipe required 4.1 times as much energy; aluminum window frames 2.8 times as much energy; and cast-iron drain/waste/vent pipe twice as much energy.

Thermal Efficiency—Because in its pure form it is less than half petroleum, vinyl is generally regarded as the most energy-efficient plastic. Vinyl roofs often carry the ENERGYSTAR® designation—because the roof reflects at least 65 percent of the sun's rays. The U-value for vinyl windows is one-third to one-seventh that for comparably priced aluminum windows. Numerous studies can be found in recent research literature on the thermal efficiency of vinyl.

Land Disposal—Vinyl products resist the corrosive conditions found in landfills, and in fact, are often used to line or cap landfills. According to research conducted by several credible organizations, it is misleading or erroneous to say that vinyl plastics decompose in landfills or give off vinyl chloride monomer.

Incineration—Studies by industry and government organizations such as the

New York State Energy Research and Development Authority have found that the presence or absence of vinyl has no effect on the amount of dioxin produced from today's regulated municipal and medical incinerators. Instead, research has shown that the incinerator operating conditions—primarily temperature—are the key to controlling dioxin formation. Similarly, the Swedish Environmental Protection Agency declared in June l996 that, "Reducing the quantity of PVC in waste does not reduce the quantity of dioxin in the waste gases." Chlorine gas is not released into the atmosphere by incineration (or recycling or landfilling) of vinyl. A majority of the chlorine present in incinerator waste comes from sources other than vinyl, such as table salt and food waste. Our research revealed that even if vinyl products were banned—as some have suggested in the past—incinerators would still need to use scrubber systems to make them environmentally acceptable. As for acid rain, power plants using fossil fuels, which produce sulfur dioxide and nitrogen oxide, are considered to be its primary cause. In Europe and Japan, studies show that only about 0.3 percent of all atmospheric acidity can be traced to the incineration of vinyl.

Recycling—A significant amount of vinyl scrap is being recycled. A 1999 study by Principia Partners found that more than one billion pounds of vinyl were recovered and recycled into useful products (in North America alone) in 1997. Post-consumer vinyl products can be recycled, but, as with any product, this requires an infrastructure in which products are collected, sorted and separated, and shipped to or purchased by end users. The economics of recycling are highly location-dependent. Vinyl can be a contaminant in recycling, as can any other material not specifically targeted in a given recycling program. Except for commingled plastics applications, different plastic materials cannot be mixed successfully in most recycled products applications. Because of its chlorine content, vinyl lends itself to automatic sorting technology, which is helpful. Reclaimed vinyl can be used in new building products, including drainage pipe, windows, flooring, exterior accessories and fencing. Today, the demand for recycled vinyl exceeds the supply.

The Vinyl Environmental Resource Center, an arm of the Vinyl Institute, links vinyl waste generators and vinyl recyclers. A directory of companies making products from recycled vinyl is available from the Vinyl Institute or on-line. See: www.vinylinfo.org.

Interview Findings on Sustainability and Vinyl in Construction

The research participants in this study, all highly sophisticated in terms of environmental stewardship and sustainability, described vinyl using the following "positive" contextual descriptors:

- Low cost and economical
- Durable
- Lightweight
- Easy maintenance
- Aesthetic with color-fast/integrated color

A majority of the chlorine present in incinerator waste comes from sources other than vinyl, such as table salt and food waste.

- Alternative
- Flexible

The participants described vinyl using the following "negative" contextual descriptors:

- Concern
- Dangerous/toxic
- Flimsy
- Petroleum product
- Unattractive
- Mid-grade, not high end
- Short term economy

When asked whether they prefer certain products made of vinyl, the research participants responded "yes" equally as often as or more often than "no" for the following uses:
Signage—22 yes, 6 no
Piping—16 yes, 12 no
Wall Coverings—16 yes, 12 no
Flooring—14 yes, 11 no
Blinds—14 yes, 14 no

Representative comments from research participants about use of products made of vinyl were both positive and "of concern," reflecting uneven knowledge even among this quite educated group.

- "Fencing is being used more and more by our firm."
- "Decking is becoming popular because of low maintenance."
- "Piping underground—no, but in residential, yes."
- "Wall coverings are okay if in proper location; vapor control is a problem."
- "Countertops—yes."
- "PVC is the gold standard of vinyl."
- "Yes, for decking with recycled materials."
- "Not just environmental issues for us. Its appearance needs to be improved."
- "No to all. We wouldn't recommend that any vinyl products be used."

When the research participants were asked about recycling vinyl and materials, 20 said that they were aware that vinyl products are composed of recycled materials and 8 said that they were unaware or uncertain.

In response to the request to rate certain vinyl products for their environmental compatibility, the research participants offered mixed reviews and indicated concerns.

What the Record Shows About Selected Vinyl Products' Performance

Piping: PVC pipe represents the largest application for PVC, accounting for nearly 50 percent of all PVC used in the United States. It is not a source of lead or of other chemical contaminants associated with metal pipe. PVC pipe is also flexible enough to resist breaking when the ground shifts naturally under weight-bearing loads. When properly designed and installed, PVC pipe has an estimated life span of more than 100 years, with little or no loss of strength.

PVC pipe does not rust, pit or corrode. It has become the leading material for large-diameter buried pipelines installed

by water and wastewater utilities, smaller-diameter waste and vent applications and cool-water delivery systems. Its durability, reliability and ability to meet water quality and fire performance standards make it a current solid choice for building owners when evaluating against alternatives. Industry newsletters report that PVC piping resists attack by cleaners and other household chemicals, and can withstand pressure surges, shock impact, general wear and abrasion.

Roofing

Vinyl roofing is relatively easy to maintain and eliminates the need for asphalt, tar and other materials used in built-up roofing. Typically, vinyl-roofing membranes are light-colored, and reflective surfaces help structures to stay cool and reduce energy use for air conditioning. In a study sponsored by the EPA and the U.S. Department of Energy, the Heat Island Group at the Lawrence Berkeley National Laboratory measured and analyzed summer air-conditioning energy savings and power-demand reduction of a large Austin, Texas, retail store that was retrofitted with a reflective vinyl roof membrane. The building was monitored with its original black roof from August 1999 to April 2000 and from May to September 2000 with the vinyl membrane. The researchers estimated that the cool roof saved 60 megawatt-hours per year or more, saving tens of thousands of dollars. Additionally, the building manager said installation of white thermoplastic roof lowered labor costs, which offset higher material cost.

Flooring

Vinyl flooring is often a preference in commercial buildings, especially those in which hygiene is a particular concern. A recent article in Sweden's leading independent building trade magazine discussed PVC flooring. It was noted that while headlines still warn about "leaking" vinyl flooring, vinyl is the preferred flooring material in public environments such as hospitals and nursery schools. One hospital that opened in 1999 undertook a thorough evaluation of various flooring materials, based on emissions limits, wear resistance, hygiene, quality, length of life, maintenance, price and cleaning cost. Vinyl was ultimately chosen.

In another example, the Good Samaritan Regional Medical Center in Phoenix enlisted the Stein-Cox Group, Inc. to design an environment for a bone marrow transplant unit that would have a home-like feel that met strict code requirements. Such transplant units must maintain a sterility akin to an operating room. The challenge was to provide aesthetics yet not collect dust. The design team created colorful patterns with vinyl flooring; faux finishes on the walls and hand-painted murals in patient rooms. The vinyl flooring had welded seams, preventing contaminants in seam areas. Because it is impervious to water, it allows frequent cleaning. And vinyl is softer and quieter underfoot than some other resilient flooring materials.

One hospital that opened in 1999 undertook a thorough evaluation of various flooring materials, based on emissions limits, wear resistance, hygiene, quality, length of life, maintenance, price and cleaning cost. Vinyl was ultimately chosen.

Wall Coverings

Vinyl is used in many commercial and residential wall coverings—especially in kitchens, baths and health care facilities—because it is durable, strong and easy to clean. These coverings meet or surpass specifications and strict industry standards. Plasticizers used in vinyl wall coverings and other products have been thoroughly researched, and there is no evidence of adverse human health effects when properly used. The wall covering industry has worked to reduce or eliminate heavy metals such as cadmium and mercury previously used as pigments, stabilizers and biocides. Standards have been established to test flame spread and smoke development of materials used on walls and ceiling, and most vinyl wall coverings meet the "Class A" requirements—the best rating.

Sources for Life Cycle Analysis

Architects and contractors need trusted information to make product selection decisions. Assessing the best material for an application in terms of its energy and environmental impact can be complicated—involving detailed analyses of each step in the production, use and disposal sequence.

Fortunately, more and more studies are in process to assess product life-cycles. The European Commission recently published an overview of the results of dozens of life-cycle studies of products made of either vinyl and competing materials. The study, "Life Cycle Assessment of PVC and of Principal Competing Materials," (http://europa.eu.int/comm/enterprise/chemicals/sustdev/pvc-final_report_lca.pdf) challenges material de-selection policies by pointing out that the performance of a durable, lasting material can outweigh concerns about the production of the material.

The study found a number of applications in which vinyl performed as well as or better than competing materials. In some cases, e.g. windows, the study found the frame material used mattered less than the quality of the design, construction and installation of the window.

There are also life-cycle tools that allow users to run their own comparisons using existing databases. Some allow users to select and weight the parameters. At least one free, online life-cycle program developed by the National Institute of Standards and Technology includes economic data. Studies done with this program, known as Building for Economic and Environmental Sustainability: (http://www.bfrl.nist.gov/oae/software/bees.html) have shown that vinyl composition tile can be environmentally preferable to linoleum.

Other Sources

In addition to life-cycle tools, there are organizations and publications that offer useful, credible information on energy and environmental issues, including the following:

Greenguard
http://www.greenguard.org

U.S. Green Building Council
www.usgbc.org

U.S. Environmental Protection Agency's Environmentally Preferable Purchasing (EPP) program
www.epa.gov/oppt/epp/database.htm

Vinyl Institute
(www.vinylbydesign.com

Design Futures Council
www.di.net

Joslyn Castle Institute for Sustainable Communities
www.ecospheres.com

Modern Materials
www.manufacturing.net/mmh/

Athena Sustainable Materials Institute
http://www.athenasmi.ca/

Building Science Corp.
http://www.buildingscience.com/

Energy & Environmental Building Association
http://www.eeba.org/

National Institute of Building Sciences
http://www.nibs.org/

National Renewable Energy Laboratory
U.S. LCI Database Project
http://www.nrel.gov/lci/

Becoming Sustainable

Vinyl is a time-tested, researched material with a general, but not perfect, safe history of use dating back more than 50 years. It is important to note that vinyl products meet a demanding range of health and safety standards established by numerous agencies including the National Sanitation Foundation, the National Fire Protection Association, all three model-building codes and the Consumer Product Safety Commission. The vinyl industry has made significant progress in putting in place the American Chemistry Counsel's Responsible Care Codes of Management Practices. Manufacturing facilities regularly check their own progress for each of the codes, using very defined measurements. Vinyl manufacturing facilities are preparing comprehensive risk management plans to comply with new federal Clean Air Act regulations. Through the Vinyl Chloride Safety Association, producers of vinyl chloride worldwide share information about ways to improve the safety and environmental performance of their manufacturing plants.

The vinyl industry seems conscientious and forward-thinking about sustainability. But because of the degree of awareness and misunderstanding among designers and architects about health, environmental and safety issues associated with vinyl, the industry has a challenge to prove its sustainability over the long run.

Vinyl is a time-tested, researched material with a general, but not perfect, safe history of use dating back more than 50 years.

Background and Objectives

Greenway Group's Counsel House Research, on behalf of the Design Futures Council, a think tank of architects, designers and construction industry leaders based in Washington, D.C., conducted this analysis of vinyl in light of new sustainability studies. There is no doubt that environmental concerns will (and should) shape the future of design, architecture and development. Leading firms around the world now offer sustainable design expertise broadly. The Design Futures Council has recently conducted several influential Leadership Summits on sustainable design; interest in the subject is growing at a phenomenal rate. Architects and contractors more than ever before, realize that design and specification of building products affects the health and well-being of users. Architects are designing environments that can inspire people and help them be productive while showing good stewardship for the planet.

The Vinyl Institute represents leading manufacturers of PVC or vinyl, vinyl feed stocks additives and vinyl packing products. The institute works to advance the vinyl industry, to sponsor scientific research on its safety, and to monitor regulatory activity affecting the industry. As supporters of the American Chemistry Council's Responsible Care® initiative, the institute's member companies are committed to environmental and product stewardship.

In our built environment, vinyl plays a significant role. About 60 percent of all vinyl is converted into products for residential and commercial building. Vinyl is widely used for water distribution, gutters and downspouts, siding, irrigation and sewer pipes, window frames, floor and wall coverings, electrical conduit, wire and cable insulation, fire-sprinkler piping and fencing. Many commercial building have vinyl roofs. In many applications vinyl replaces traditional materials including concrete, wood, copper and aluminum. Tradespeople who install building materials have set their operations and training around this lightweight and often-flexible material.

The vinyl industry has shown increasing attention to sustainable design and asked the Design Futures Council and Greenway Consulting to conduct a current analysis of vinyl products in building.

Research Steps

- Provide analysis of vinyl for use in the construction industry from the perspective of green and sustainable design.
- Explore vinyl's potential advantage as a sustainable material.
- Conduct a qualitative analysis of attitudes of leading architects working in private practice, industry and education regarding current and future use of vinyl products, in the context of green or sustainable design.
- Provide analysis of the barriers to specification of vinyl products as sustainable.
- Provide analysis of strategic implications for future consideration.

Methodology

In February and March 2004 the Greenway Group's Counsel House Research conducted a study of vinyl in building. We conducted a review of current studies, findings and literature worldwide with analysis conducted and supervised by Ann Delatte, Ph.D. and James Cramer, Hon. AIA. Greenway Group interviewed architects at 28 leading firms or institutions currently working with sustainability of design and development. Eligibility required them to have been delegates to the 2003 Leadership Summit on Sustainable Design. Study participants were selected and recruited by the Greenway Group. The research was organized by Greenway Group's Atlanta office. The research is highly qualitative in nature and the survey responses are not intended to be projectable to the entire industry. Leading indicator "signals" were sought to help sort the strength, barriers and possible strategies.

The firms, organizations and institutions participating in the research include principals from the following list. Their opinions on vinyl's place in design range from firmly against its use, to entirely convinced of its merits and safety:

- **Auburn University College of Architecture**
- **BWBR Architects**
- **DuJardin Design Associates**
- **Durrant Architects, Engineers and Planners**
- **Envision Design**
- **Gensler**
- **GSBS**
- **Hardison Komatsu Ivelich and Tucker**
- **Heitman Architects**
- **Hoffman Construction**
- **HOK**
- **Joslyn Castle for Sustainable Communities**
- **Leonard Parker Associates**
- **Luckenbach/Ziegelman Architects**
- **Mackey Mitchell Associates**
- **McBride Kelley Baurer Associates**
- **McKissack & McKissack**
- **Milliken Design, a design innovation department of Milliken Carpet and Textiles**
- **Nelson Associates**
- **Peckham & Wright**
- **Slater Paull Architects**
- **Swaback Partners**
- **Solutions**
- **Thompson Ventulett Stainback (TVS)**
- **The University of Nebraska College of Architecture**
- **USG Corporation**
- **Weidt Group**

The research participants came from 15 states and all were in current leadership positions. Participants' experience in green and sustainable initiatives greatly exceeds the average in regard to professionals who specify products today. These research participants have significant influence on product specification in their organizations as current thought leaders in green and sustainable design. As for years of experience in the architecture and construction industry, 36 percent have been in the industry from 25-30 years; 29 percent 10 to 24 years; 25 percent 30 to 39 years; and almost 11 percent have been working in the industry for more than 40 years.

In our built environment, vinyl plays a significant role. About 60 percent of all vinyl is converted into products for residential and commercial building.

James P. Cramer, Hon. AIA

Cramer is chairman and principal of Greenway Consulting. He worked as publisher of two leading architecture journals for 12 years before becoming senior vice president and later, CEO (1988-1994) of the American Institute of Architects. In 1994 he became Chairman of the Greenway Group, an independent research, trends analysis, and strategy consultancy. Greenway's clients include the world's leading design and architecture firms and Fortune 500 corporations. A strategist, educator, and speaker on trends within the A/E/C industry, Cramer is the author of *Design + Enterprise, Seeking a New Reality in Architecture* and co-author of *How Firms Succeed, A Field Guide to Design Management*. He is the editor of *DesignIntelligence*.

Ann Perkins Delatte, Ph.D.

Delatte is a Senior Consultant with Greenway where she specializes in industry trends research and analysis as well as leadership and human resource evaluation. She has over 25 years experience in research consulting, strategy and analysis experience with professional firms and the non-profit and government sectors. Prior to her work with Greenway Group she held positions with Towers Perrin, Georgia State University, and The American Institute for Research. She founded and directed a university-based degree program in human resource management for the Department of Labor employees. While with Towers Perrin, Delatte designed/directed research and education projects involving strategic planning.

Design Futures Council

To order additional copies of this report, please contact the Design Futures Council at (800) 726-8603.