

Alternatives to PVC: An Economic Analysis

Frank Ackerman¹

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This much should be self-evident: a material should not be used in green buildings if it is uniquely toxic or carcinogenic, if it causes high levels of harm to workers, communities, and the natural environment both in production and in disposal. Rather, replacement of such a material with less toxic alternatives should be a priority for environmentally concerned architects, designers, and builders.

I will argue that there is one high-volume, highly toxic building material that should be replaced: polyvinyl chloride (PVC). It is the only one of the common plastics that is chlorinated; as a result, its production and disposal give rise to emissions of dioxin, vinyl chloride monomer, and other dangerous, chlorinated organic pollutants. Although PVC has become ubiquitous, and is known for being cheap and convenient, there are alternatives that can replace it in every current use. The incremental cost for alternatives differs from one product to another – in some cases, as we will see, there is little or no additional cost for using less hazardous materials. In medical institutions, where the movement to replace PVC on health grounds is advancing rapidly, prices of alternatives have plummeted as major buyers have begun to demand chlorine-free products. The same could and should happen in construction.

Since today's session includes a representative of the plastics industry and an expert on life-cycle analysis, let me begin with a word about how my views relate to their topics. I am definitely not here to criticize all use of plastics; no other plastics cause such severe health effects, in production or disposal, as PVC. Indeed, the most practical alternative to PVC is frequently a polyethylene or other non-chlorinated plastic product. The question is not, "Plastics: good or bad?" Often the question is "How can we replace bad plastics with better ones?"

Life-cycle analyses have proliferated in recent years, seeking to evaluate alternative materials on a broad range of environmental criteria. A number of these studies suggest that PVC is at least as "green" as alternative materials. On closer examination, it turns out that many such studies pay little or no attention to toxic and carcinogenic impacts, but focus on questions such as energy use and several varieties of common, low-toxicity emissions. It is interesting to know that PVC does relatively well by standards of energy use and criteria pollutant emissions, but these findings are not relevant to the main health and environmental problems caused by the vinyl life cycle.

¹ Global Development and Environment Institute, Tufts University, Medford MA 02155, e-mail Frank.Ackerman@tufts.edu. Thanks to Rachel Massey and Regina Flores for extensive research assistance in the preparation of this paper.

In the early 1990s I led a research team at the Tellus Institute, a non-profit environmental research group in Boston, in a massive life-cycle analysis of all the packaging materials in widespread use in the U.S. economy at the time. Unlike many other analyses, our criteria for evaluation of the materials were heavily weighted toward human health impacts. None of us on the research team knew about the problems with PVC when we started. We were all but certain that we knew in advance how the study would turn out – and we were wrong. To our complete surprise, our quantitative results singled out the PVC life cycle as far more carcinogenic than other packaging materials, including all the other common plastics.²

Chlorinated Carcinogens

The remarkable success of PVC in penetrating many different markets, and the numerous health hazards that it creates, have a single cause: PVC is the only common plastic that contains chlorine. Other plastics, including polyethylenes, the most widely used polymers, are made entirely from hydrocarbons. PVC, in contrast, combines hydrocarbons with chlorine – which turns out to be both a versatile and a deadly combination.

PVC in its pure form has limited uses. It is rigid, and becomes brittle with prolonged exposure to light. However, the shape of the chlorinated molecules allows many different additives to be mixed in, giving PVC a broad range of possible characteristics. Depending on the product, the additives may include plasticizers to make it less rigid, stabilizers to overcome light sensitivity, and dyes to achieve the desired colors.

The unique chemistry of PVC is also the source of the bad news. Many chlorinated organic compounds are known to be toxic or carcinogenic, and many more, similar compounds have yet to be tested. The production of chlorine, and its subsequent use in the production of PVC, creates many of these hazardous chemicals as byproducts.³

In nature, chlorine is normally harmless, bound up in inorganic molecules such as sodium chloride (ordinary salt). Chlorine in its pure, and dangerous, form is an unwanted byproduct of the chemical industry, which splits salt molecules by electrolysis to obtain sodium, for use in making caustic soda. The only way to dispose of the chlorine is to use it in another industry – for bleaching paper or disinfecting water, for instance – or to make it into other products. Over the years these products have included: household bleach; DDT and other hazardous pesticides; PCBs; perc, the dry cleaning fluid that is now recognized as a health hazard; and the poison gas that proved so lethally effective in World War I.

However, many of these chlorinated chemicals are no longer on the market, or have limited potential for growth. The largest and most rapidly expanding market today is the

² The study was published by the Tellus Institute in 1992. A summary of the results appears in Frank Ackerman, *Why Do We Recycle? Markets, Values, and Public Policy* (Island Press, 1997), Chapter 5.

³ See the detailed study by Joseph Thornton, *Pandora's Poison: Chlorine, Health, and a New Environmental Strategy* (MIT Press, 2000) for documentation. Links to additional relevant research are available at <http://www.greenpeaceusa.org/media/publicationstext.htm#toxics>.

production of PVC, which absorbs more than 40% of all industrial chlorine.⁴ As a result of this extensive use of chlorine, every step of the PVC life cycle involves remarkably hazardous emissions.

Dioxin, the most potent carcinogen ever encountered, is emitted in the production of PVC, and again when PVC is burned. Municipal waste incinerators are a leading source of dioxin, and half of the chlorine in incinerators that ends up in dioxin comes from PVC waste. Dioxin is also created when PVC burns accidentally in fires, or intentionally in open burning of waste in rural areas. As long as construction waste on rural job sites ends up in burn barrels, vinyl building materials are spreading dioxin across the countryside.

Other chemical hazards are created in even larger quantities. Vinyl chloride, the essential building block from which PVC is assembled, is a proven human carcinogen. Workers in PVC production facilities and residents of neighboring communities are inevitably exposed to vinyl chloride emissions; it was these emissions that determined the outcome of our Tellus study. And there are many more chlorinated organic compounds, byproducts of the production and disposal of PVC, which are known to be hazardous to our health.

Moreover, the additives in PVC are themselves often toxic. Stabilizers include dangerous metals such as lead, cadmium, and tin, while plasticizers include a type of organic compounds, called phthalates, that are endocrine disrupters. In many cases, these additives leach out into the environment, changing the properties of the vinyl product and endangering those who come into contact with it. Concern about leaching of toxic additives has been a major factor in the growing rejection of PVC in medical supplies, but it is important in other areas as well. When PVC ends up in landfills, the additives can seep out into leachate, the heavily polluted water that collects in landfills and, all too often, leaks into nearby water supplies.

Markets for PVC

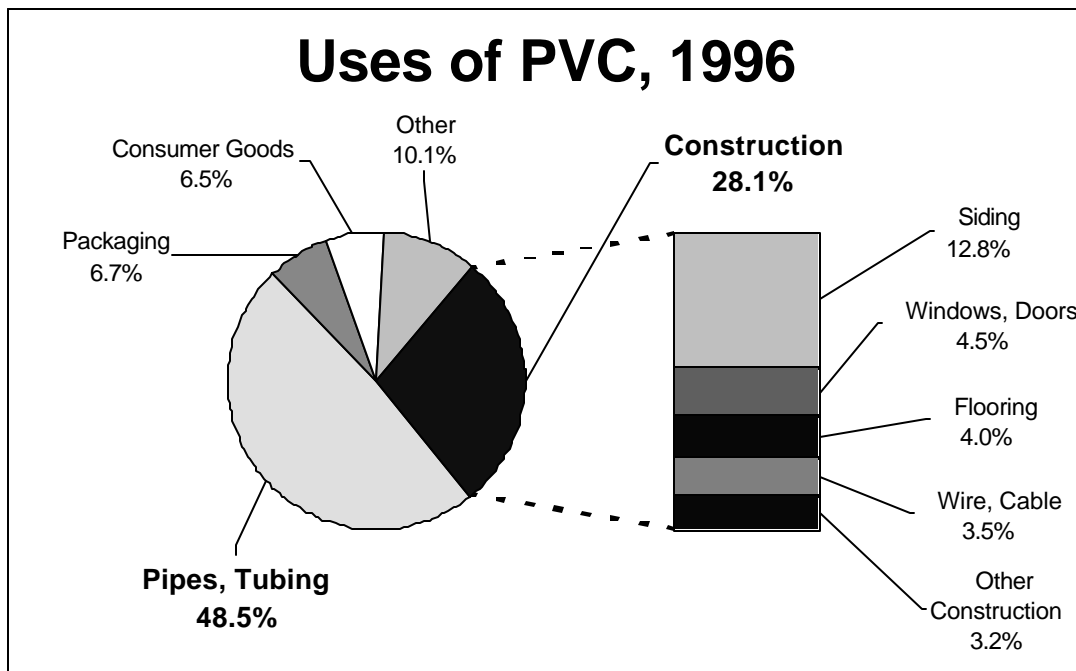
Sales of PVC have grown rapidly in recent years, reaching 14.6 billion pounds in the U.S. and Canada in 2001, or 46 pounds per person. The uses of PVC are shown in the following graph (next page). Although vinyl can be found in products ranging from packaging and lawn furniture to hospital supplies and automobile interiors, the graph shows that more than three-fourths of all PVC ends up in pipes and construction materials.

Pipes (including tubing, conduits, and pipe fittings) account for almost half of PVC sales. Most of this consists of municipal water and sewer pipes, outdoor drainage pipes, and industrial and agricultural pipes. However, two types of PVC pipes are in fact construction materials: the DWV (drain/waste/vent) plumbing inside buildings, where use of PVC has become the norm; and electrical conduits, where PVC competes with steel.

Construction materials, excluding pipes, represent more than a quarter of PVC use. Vinyl siding is the largest single construction market, followed by windows and doors, flooring, and

⁴ Thornton, Table 6.3, p. 247. The 40% figure combines PVC production and exports of the PVC precursors EDC/VCM, which are used to produce PVC in other countries.

wire and cable. Roofing, wall coverings, and a wide range of other building materials make up the remainder.



The Cost of Replacements

How much does it cost to replace PVC with less toxic, non-chlorinated materials? It is widely believed that the cost differential is enormous: an otherwise knowledgeable Home Depot representative recently offered me his guess that vinyl-free construction would have tripled the price of his new home. The facts do not support any such conclusion. In terms of systematic comparisons, there were three efforts in the mid-1990s to calculate the cost of replacing PVC throughout the economy. Converted to today's dollars, all three studies found that going PVC-free would increase average costs by about \$1.00 per pound for non-pipe applications. The studies disagreed on the cost of switching to non-PVC pipes, with one as high as \$1.40 per pound, while the most recent and comprehensive study put the incremental cost of non-PVC pipes at only \$0.15 per pound of PVC replaced.⁵

All three studies, though, are somewhat dated; the most recent, published by Environment Canada in 1997, analyzes data for the Canadian economy in 1993. It is not obvious that its conclusions apply to the U.S. economy almost a decade later. The range of available alternative products has shifted, with some older options, like aluminum siding, losing market share while others, such as polyethylene pipe, are growing in importance.

To explore the range of options for PVC-free construction today I will discuss four product areas. Two of them, flooring and roofing, provide easy, economical options for

⁵ Based on my research in progress; details available on request.

eliminating PVC, where alternative materials offer superior performance; the other two, vinyl siding and DWV plumbing, are currently harder to replace.

Flooring. There are numerous ways to make floors. In addition to high-end options such as hardwood floors or ceramic tiles, there are many varieties of carpeting, wood composite products, traditional materials such as cork or linoleum, rubber flooring – and vinyl and other synthetic floor coverings. Vinyl is less durable than many of the alternatives, requiring more maintenance and more frequent replacement. As a result, materials with a higher purchase price may have a lower life cycle cost on an annualized basis.

You don't have to take my word for it; that's the conclusion that the U.S. Navy reached in a detailed assessment of decking materials for its ships.⁶ In that assessment the Navy tested Stratica, a new, chlorine-free, composite flooring material, on ten ships, covering a total of 37,800 square feet. Stratica consists of two layers, each an ethylene-based copolymer with a variety of metals and minerals added; the surface layer is a DuPont product that is also used on the surface of golf balls. The advantages of Stratica, according to the Navy, are that it has a life expectancy of 10 years, versus 5 for vinyl tile, and that it requires about one-third as much labor for maintenance. The maintenance costs were the dominant factor, as shown by the Navy's estimates of costs per square foot over a ten-year span:

	Total Life-Cycle Cost (\$/sq. ft. over 10 years)	
	Stratica	Vinyl tile
Purchase and installation	\$7.00	\$6.25
Repair	\$4.00	\$6.50
Maintenance labor	\$192.24	\$587.78
Total	\$203.24	\$600.53

According to *Environmental Building News*, Stratica is ISO 14001 certified, and performed better than vinyl flooring on many criteria in a life cycle analysis by the Fraunhofer Institute in Germany. *EBN* notes that Stratica's "biggest environmental selling point, however, is that it offers a 'drop-in' replacement for vinyl." The manufacturer, a company that also produces vinyl tile, tactfully states: "Stratica provides a solution for the customers who prefer, through their own choice, to avoid chlorine... Stratica is therefore suitable for customers who simply prefer, through their own choice, to avoid plasticizers."⁷

Roofing. Roofs, like floors, can be made from many materials. An increasingly popular style, single-ply or flexible membrane roofing, is most often made from either of two non-

⁶ "Implementation Assessment for Maintenance Free Decking," memorandum prepared for the Under Secretary of the Navy by the Commander, Naval Supply Systems Command, January 14, 2000.

⁷ "A New Chlorine-free Competitor to Vinyl Flooring," *Environmental Building News* vol. 7 no. 10, November 1998.

chlorinated plastic materials, TPO (thermoplastic elastomer polyolefin) or EPDM (ethyl propylene diene monomer), or from PVC. The installed cost is similar for all three, and usually cheaper than for other styles of roofing. In some cases, the alternatives are lower-priced than vinyl. A TPO vendor reports that two almost identical schools in western Massachusetts, in Longmeadow and Bellamy, recently installed roofs of about 120,000 square feet. The one that chose vinyl paid \$919,000, while the one that chose TPO paid \$638,000.⁸ The vinyl industry advertises the fact that white vinyl roofs increase the energy efficiency of a building, and have been recognized by EPA's Energy Star program. However, all three membrane materials can be made white, in manufacturing or in painting; the New Orleans Superdome has a mammoth EPDM roof painted white.

An in-depth look at roofing technology comes again from a military source, this time from the U.S. Army's Construction Engineering Research Laboratory (CERL). Launching a long-term investigation into PVC membrane roofing, a 1981 CERL report noted anecdotal evidence of PVC roof failures in both Switzerland and the United States, and said, "The two most serious PVC membrane problems are embrittlement from loss of plasticizer or from exposure to ultraviolet rays and excessive shrinkage."⁹ A 1997 paper, reporting on CERL's ten-year field study of three PVC roofs at military installations, found that the performance of two of the roofs was "generally satisfactory," whereas "problems related to shattering and splitting" occurred at the third.¹⁰ The paper offers a detailed technical comparison of samples of the three roofs, noting some (but not conclusive) evidence that the roof that shattered may have lost more plasticizer than the ones that remained intact.

In light of this experience, it may not be surprising to learn that sales of TPO roofing are growing faster than PVC, and EPDM also has enthusiastic advocates in the industry. In roofing, as in flooring, there is no cost penalty, and a noticeable gain in performance, for adopting alternatives to PVC.

Siding. Not every use of vinyl is as easy to replace as flooring and roofing. Siding is the largest single use of vinyl in construction; as seen in the graph above, it accounts for about one-eighth of all PVC. Sales pitches for vinyl siding promise the homeowner a maintenance-free exterior: "You'll never paint again." As the owner of a traditional, wood-shingled New England house that needed repainting this year, I understand the appeal of this promise (although I would personally reject vinyl siding on aesthetic as well as environmental grounds). An effective alternative will have to match or rebut vinyl's claim to be maintenance-free. In fact, anecdotal evidence suggests that vinyl siding does discolor over time, and may require painting, if not replacement.

⁸ Personal communication, Ted Boylan, November 2002.

⁹ Myer J. Rosenfeld, "An Evaluation of Polyvinyl Chloride (PVC) Single-Ply Membrane Roofing Systems," U.S. Army Corps of Engineers Technical Report M-284, March 1981. Available at <http://www.rci-mercury.com>

¹⁰ David M. Bailey, Stuart D. Foltz, Walter J. Rossiter Jr., and James A. Lechner, "Performance of Polyvinyl Chloride (PVC) Roofing: Results of a Ten-Year Field Study," *Proceedings of the Fourth International Symposium on Roofing Technology*, September 1997. Available at <http://www.rci-mercury.com>

As the movie “Blue Vinyl” documents in entertaining detail, it is difficult to find an affordable alternative that matches the performance of vinyl siding at present. Aluminum siding, a leading alternative in years past, has all but disappeared from the market. However, new, low-maintenance products have been developed that show promise for the future, including fiber-cement siding, engineered wood products, and TPO siding. The most successful of these to date, fiber-cement, contains no chlorine, and is at least as durable and attractive as vinyl – much more so, according to its enthusiasts.¹¹ Unfortunately, fiber cement contains silica, and can give rise to silica dust in manufacturing or installation. Inhalation of silica dust can cause silicosis, a devastating lung disease. Unless the silica dust problem can be controlled, fiber cement poses an occupational health hazard to the workers who make and install it.

In view of the size of the siding market, finding a non-toxic, PVC-free alternative remains an important task for those interested in green buildings. More research and development is needed, either on controlling the silica dust problem in fiber cement or on identifying another, healthier alternative siding material.

Plumbing. About half of all PVC is used in pipes. In municipal water and sewer systems, the largest market for PVC pipes, there is active, ongoing competition between PVC, polyethylene, and traditional iron and cement pipes. In the plumbing inside buildings, hot water pipes get too hot to be made of PVC; thus hot and cold water lines into the building are usually made of copper. On the other hand, pipes that take wastewater away – the DWV (drain/waste/vent) pipes – are almost always made of PVC today. Ease of installation is the major selling point for PVC drain pipes: anyone can cut them to size, and join them with pipe cement. In this case, concern for occupational health adds to the urgency of finding alternatives. The purple pipe cement that is used to join PVC pipes is itself toxic, and threatens the health of contractors, plumbers, and homeowners who use it.

While the alternatives are not common, they can be found. Both polyethylene and metal pipes can be used for DWV applications. One major “green building” effort, the Sheraton Rittenhouse Square Hotel in Philadelphia, used black metal drain pipes rather than PVC. Co-owner Barry Dimson says that the metal tubing was comparable in price to PVC. Dimson, who describes the Sheraton Rittenhouse as “the first environmentally smart hotel in the continental United States,” explains that the hotel chose to avoid vinyl wall coverings, carpeting and tile, as well as drain pipes. In his view, the overall cost of the hotel’s ambitious green building program was modest, and frequently led to improved performance.¹²

Conclusion: Following the Market, and Leading It

In some important cases, such as flooring and roofing, it is easy to reject vinyl today. There are PVC-free alternatives that offer superior performance at the same or even lower life-

¹¹ Carol Ochs, “Fiber-Cement Siding: Making a Dent in Housing Market.” *Realty Times* (January 22, 2002). Available at http://realtytimes.com/rtnews/printtrpages/20020122_cement.htm. Glenn Haege, “New Alternative To Vinyl Siding Offers The Beauty Of Natural Wood,” *Detroit News* (September 29, 2001). Available at <http://www.detnews.com/2001/homestyle/0110/04/e28-305983.htm>.

¹² Personal communication from Barry Dimson, September 2002. See also Barry Dimson, “The Economics of Green Hotels”, January 2002, and <http://www.sheraton.com/philadelphiarittenhouse>.

cycle costs. When short-term economic considerations, performance standards, and long-term environmental concerns all point in the same direction, there is no reason to look anywhere else.

In other cases, such as siding and plumbing, the situation is more complex. There are alternatives to PVC that offer comparable or better performance, but they are not widely available; only the PVC products are currently mass-produced and mass-marketed. As a result, the alternatives are likely to be more expensive. It is natural to ask how much more expensive the PVC-free products are – but there is often no fixed answer.

When markets for new products expand, prices generally drop, as demonstrated by the recent history of the computer industry and other consumer electronics. Economists refer to this as “economies of scale,” a pervasive fact of life. The unit price of almost anything is much lower if you buy a million rather than a thousand units, both because you have more clout in the market, and because it is genuinely cheaper to produce things in huge batches.

An example from the field of medical supplies demonstrates the flexibility of prices, and the role that a major purchaser can play in shaping the market. Disposable examination gloves, used in enormous quantity by health care providers, are frequently made of PVC. A once-common alternative, latex gloves, are increasingly being rejected because they cause severe allergic reactions in some patients. The remaining alternative, nitrile gloves, appear to cost two to four times as much as PVC gloves when bought in small quantities. However, medical institutions have grown concerned about the health effects of PVC, and have begun to specify non-PVC supplies in their purchasing practices. When Kaiser Permanente, the giant West Coast HMO, placed an order for 43 million nitrile gloves, their supplier offered a price competitive with PVC gloves. As production expands to fill Kaiser Permanente’s order, the price of nitrile gloves will likely fall for smaller customers as well.

Much the same could happen in building materials. Individual homeowners or small contractors cannot play the role of Kaiser Permanente, but major builders, government agencies, and other institutional buyers can. The larger the buyer, the greater the potential to transform the market and jump-start the mass production of promising new, less toxic alternatives to PVC. Is the Sheraton Rittenhouse large enough to change what is available on the market? Their orders launched a successful Boston-area producer of environmentally conscious bedding and upholstery (from whom I first heard the hotel’s story). Markets and price differentials are dynamic, ever-changing phenomena; a snapshot of what is profitable today is only part of the story of where the market is going tomorrow.

In conclusion, the details of different product lines should not obscure the underlying message: the toxicity of the PVC life cycle means that the green building movement should put a priority on eliminating vinyl in every application. Happily, doing the right thing is already profitable in some cases, such as flooring and roofing. But it is important to lead the market as well as following it. In other cases, there is a need for more research and development, and for the pioneering orders that move the market toward mass production of green alternatives. As well as acting on what is already available, we should advocate and celebrate the actions that will help make doing the right thing more profitable tomorrow than it is today.