Chapter 1

Executive Summary

Contents

	Page
PROJECT DESIGN AND THE ENVIRONMENT	4
GREEN DESIGN	6
Design Tradeoffs	8
Environmental Aspects of Products and Systems	8
Policy Implications	10
GROWING INTEREST IN GREEN DESIGN	10
SHAPING ENVIRONMENTAL POLICIES THAT ENCOURAGE GREEN DESIGN	13
Current Federal Efforts Related to Green Design	14
Long-Term Options	15
GUIDING PRINCIPLES FOR POLICY DEVELOPMENT	18
CONCLUSION	20

Box

Box	*Page*
l-A. Design and Materials Management in the Auto Industry	11

Figures

Figure	*Page*
1-1. Stages of the Product Life Cycle	4
1-2. "Solid" Wastes as Defined Under the Resource Conservation and Recovery Act (RCRA)	6
1-3. The Dual Goals of Green Design	8
1-4. Cross-Section of a Snack Chip Bag	9
1-5. Eco-labels Around the World	12

Tables

Table	*Page*
1-1. Federally Funded Programs Related to Omen Design	15
1-2. Policy Options That Could Affect Materials Flows	17

Chapter 1
Executive Summary

Policymakers should be concerned with product design for two reasons. One is to improve U.S. industrial competitiveness. A strong domestic design capability can slash product development time, improve quality, and reduce the cost of U.S. products. The National Research Council has estimated that 70 percent or more of the costs of product development, manufacture, and use is determined during the initial design stages.[1] Thus, design is a critical determinant of a manufacturer's competitiveness.

The second reason is that product design is a unique point of leverage from which to address environmental problems. Design is the stage where decisions are made regarding the types of resources and manufacturing processes to be used, and these decisions ultimately determine the characteristics of waste streams.[2] By giving designers incentives to consider the environmental impacts of their choices, policymakers can address environmental problems that arise throughout the product life cycle, from the extraction of raw materials to final disposal.[3]

The two design goals of enhancing competitiveness and protecting environmental quality can be consistent. Design strategies that reduce production costs and improve quality often have the benefit of generating less waste and pollution. Moreover, many companies are already using the environmental attributes of their products in their marketing strategies, and polls suggest that consumer demand for "green" products is likely to grow.[4] Many observers believe that those companies that are able to design high-quality, environmentally sound products will enjoy a competitive advantage in the 1990s and beyond.

In a recent review, the National Research Council found that the quality of U.S. engineering design is generally poor, and recommended that the Federal Government make engineering design a national priority to improve competitiveness.[5] In the present study, the Office of Technology Assessment (OTA) finds that better product design offers new opportunities to address environmental problems, but that current government regulations and market practices are not sufficient to fully exploit these opportunities. Therefore, integrating an environmental component into policies to improve U.S. design capabilities is an important policy objective. But policymakers should be careful in how they attempt to achieve this objective. Inappropriate regulation of the environmental attributes of products could perversely lead to more wastes being generated, and could also adversely affect competitiveness.

These findings are particularly relevant in the light of congressional debate concerning the reauthorization of the Resource Conservation and Recovery Act (RCRA) of 1976, the major Federal statute concerning solid waste. The reauthorization debate involves many issues that could affect the design of products, including mandatory recycled content, reduced toxic chemical content, government procurement of recycled products, and environmental labeling, as well as controls on products that cause special waste management problems such as automobile batteries, used oil, and tires.

In reauthorizing RCRA and other environmental laws, Congress can influence product design in two ways. First, it can enact additional environmental regulations —for example, requiring that manufacturers incorporate recycled materials into new products or take back discarded products from consumers. Second, Congress can move toward a strategy of harnessing market forces to encourage manufacturers to make environmentally sound decisions—for example, instituting a fee-rebate system based on the

1 National Research Council, *Improving Engineering Design: Designing for Competitive Advantage* (Washington DC: National Academy Press, 1991).

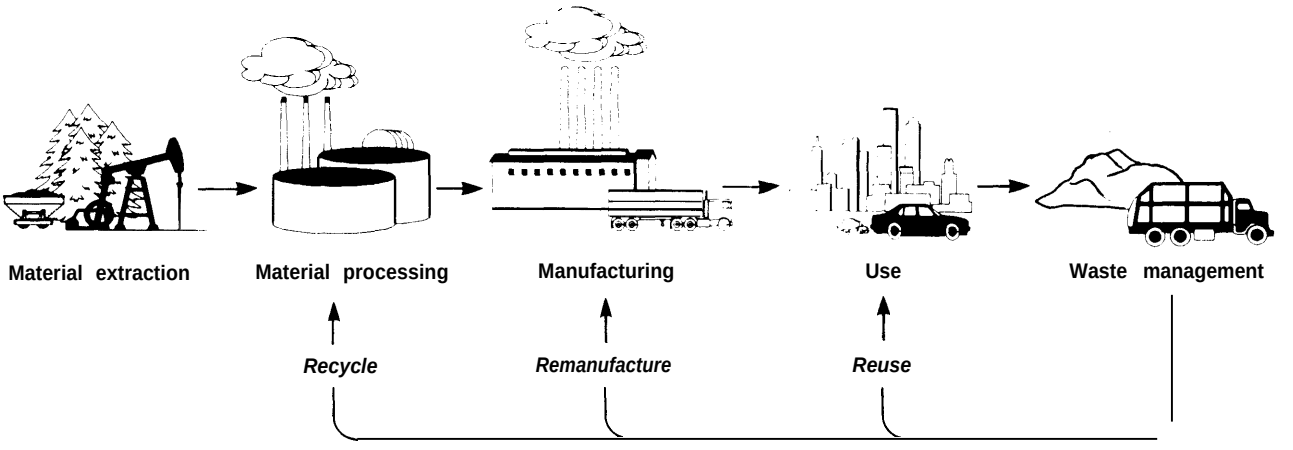
2 While this report focuses primarily on product design rather than process design, it should be recognized that the two are closely related. Many of the research needs and incentives discussed here for product design also apply to process design.

3 As used here, the term "designers' refers to all decisionmakers who participate in the early stages of product development. This includes a wide variety of disciplines: industrial designers, engineering designers, manufacturing engineers, graphic and packaging designers, as well as managers and marketing professionals.

4 Green products are those whose manufacture, use, and disposal place a reduced burden on the environment.

5 National Research Council, op. cit., footnote 1,

Figure l-l-Stages of the Product Life Cycle



Environmental impacts occur at all stages of a product's life cycle. Design can be employed to reduce these impacts by changing the amount and type of materials used in the product, by creating more efficient manufacturing operations, by reducing the energy and materials consumed during use, and by improving recovery of energy and materials during waste management.

SOURCE: Adapted from D. Navin chandra, The Robotics Institute, Carnegie Mellon University, personal communication, March 1992.

energy efficiency of products, or taxing the industrial emissions of certain toxic chemicals.

Each approach has advantages and disadvantages: regulations can produce swift and predictable results, but they can also impose unnecessary costs on industry and stifle environmentally innovative designs. Economic incentives can provide flexibility, but they can be expensive to administer and are often politically unpopular. The challenge for Congress is to employ a mixture of regulations and economic instruments to give designers the incentives to make choices that promote RCRA's goals of protecting human health and the environment.

PRODUCT DESIGN AND THE ENVIRONMENT

Products affect the environment at many points in their life cycle (figure l-l). The most visible impact is municipal solid waste (MSW). The trash generated by U.S. households and commercial establishments averages about 4 pounds per person each day. In 1988, the United States generated some 180 million tons of MSW. Landfills in many States are reaching their permitted capacity, and there is increasing public opposition to siting new waste management facilities.

About one-third of MSW by weight consists of product packaging, which has become a major target of environmental policies around the world. Better packaging design can reduce the quantity of this waste significantly. For example, at a recent conference, packaging designers concluded that—given the commitment of top management—new designs could reduce the weight of packaging by an average of 10 percent in 1 year. This would mean a 3 percent drop in MSW from this source alone.

Less visible but potentially more serious environmental impacts occur during raw material extraction, material processing, and product manufacturing. U.S. industry generates some 700 million tons of "hazardous waste" and some 11 *billion* tons of ''non-hazardous solid waste (figure l-2a).[6] Although the weight of industrial and municipal solid waste cannot be compared directly,[7] these production wastes clearly dwarf municipal solid wastes in their quantity and environmental impact (see figure l-2b). Product design decisions can have a direct

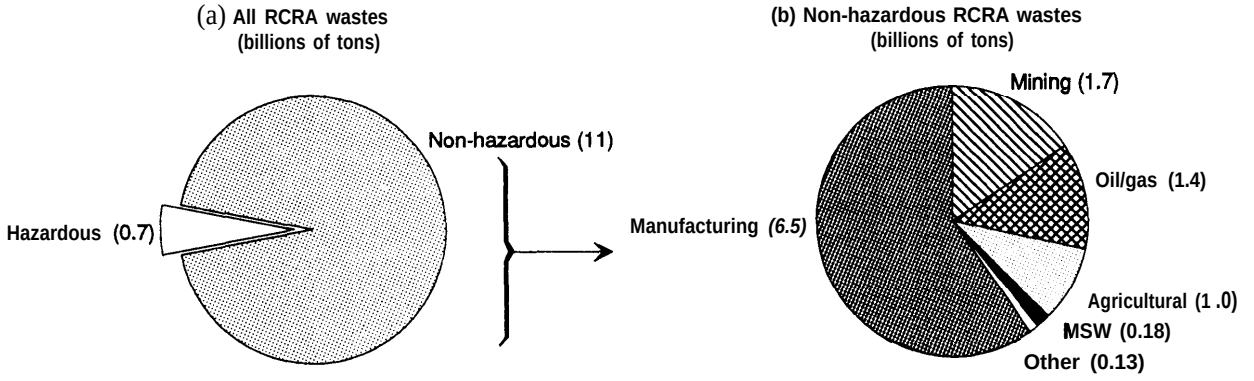
[6] The terms *hazardous* and *non-hazardous are* defined by RCRA subtitles C and D, respectively. See U.S. Congress, Office of Technology Assessment, ***Managing Industrial Solid Wastes From Manufacturing, Mining, Oil and Gas Production, and*** Utility ***Coal Combustion, OTA-BP-O-82*** (Washington, DC: U.S. Government Printing Office, February 1992).

[7] Up to 70 percent of the weight of industrial solid waste (which includes mining, oil and gas, and manufacturing wastes) consists of wastewater contained in sludges and aqueous solutions.

Photo credit: Environmental Protection Agency

Although municipal solid waste is the most visible result of our consumer society (above), industrial waste streams are a much larger and more serious problem (left). Product design decisions have a direct impact on both industrial and postconsumer waste streams.

Figure 1-2–''Solid" Wastes as Defined Under the Resource Conservation and Recovery Act (RCRA)



Much of the solid waste produced in the United States is not directly generated by consumers. Municipal solid waste, the focus of much public concern, represents less than 2 percent of all solid waste regulated under RCRA. in contrast, Industrial activities produce about 700 million tons of hazardous waste (a) and about 11 billion tons of non-hazardous wastes (b).

NOTE: All numbers are estimates. The non-hazardous waste total has been rounded to reflect uncertainty. Much of the "solid" waste defined under RCRA, perhaps as much as 70 percent, consists of wastewater. The terms hazardous and non-hazardous refer to statutory definitions of Subtitles C and D of RCRA, respectively. The mining wastes shown in (b) exclude mineral processing wastes; the oil/gas wastes in (b) exclude produced waters used for enhanced oil recovery; the "other" category in (b) includes wastes from utility coal combustion.

SOURCE: Adapted from U.S. Congress, Office of Technology Assessment, *Managing Industrial Solid Wastes From Manufacturing, Mining, Oil and Gas Product/on, and Utility Coal Combustion, OTA-BP-O-82* (Washington, DC: U.S. Government Printing Office, February 1992).

influence on the manufacturing component of these wastes (about 6.5 billion tons).

Finally, some of the most serious environmental impacts may occur during the actual use of the product. This is particularly true of products that are consumed or dissipated during their use, for example, chlorofluorocarbon (CFC) solvents and coolants, fossil fuels, and pesticides. The environmental releases from these dissipative products can be much larger than those from the associated industrial processes. For example, the State of New Jersey collects data on industrial inputs and outputs of hazardous substances. The data indicate that in 1990, 55 to 99 percent of industrial inputs of five toxic heavy metals (mercury, lead, cadmium, chromium, and nickel) was converted into products (i.e., not released as industrial waste), depending on the metal.[8] Product reformulation and substitution for toxic constituents can help to address these problems.

Behind each of these environmental impacts are critical decisions made during product design. The materials used, energy requirements, recyclability, longevity, and many other environmental attributes of products result directly from design decisions. Once a product moves from the drawing board into production, its environmental attributes are largely freed; the key, therefore, is to bring environmental concerns into the front end of the design process.

GREEN DESIGN

Product design is a process of synthesis in which product attributes such as cost, performance, manufacturability, safety, and consumer appeal are considered together. In general, products today are designed without regard for their overall impact on the environment. Nevertheless, many health and environmental laws passed by Congress do influence the environmental attributes of products. Some, such as the Clean Air Act, Clean Water Act and Resource Conservation and Recovery Act, do so indirectly, by raising industry's costs of releasing wastes to the air, water, and land. Others, such as the Toxic Substances Control Act and the Federal Insecticide, Fungicide, and Rodenticide Act, control the use of hazardous chemicals and pesticides directly.

Government regulations typically influence the design process by imposing external constraints, for example, compliance by auto designers with Corpo-

[8] Some heavy metals incorporated into products are eventually recycled, but recycling rates very substantially by material. For example, more than 50 percent of lead is recycled, but nearly all cadmium is released into the environment.

Photo credit: Courtesy *of Discover* Magazine (July 1990)

Some bacteria can store energy in polymer-bearing granules that can be collected and made into truly biodegradable packaging like these plastic bottles made from Alcaligenes bacteria by ICI, Ltd.

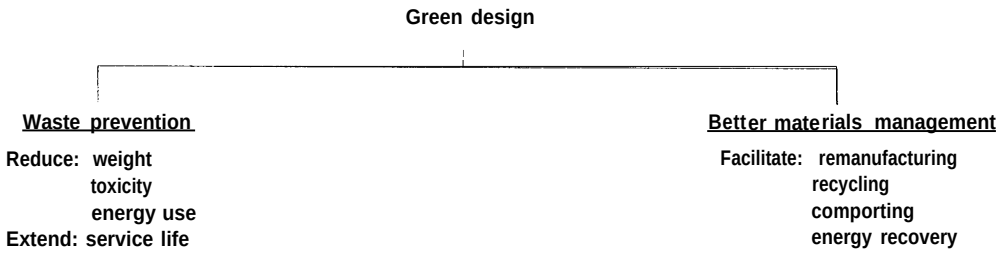
rate Average Fuel Economy (CAFE) standards, and with auto emissions standards under the Clean Air Act. OTA uses the phrase "green design" to mean something qualitatively different: a design process in which environmental attributes are treated as *design objectives,* rather than as *constraints.* A key point is that green design incorporates environmental objectives with minimum loss to product performance, useful life, or functionality.

In OTA's formulation, green design involves two general goals: *waste prevention* and *better materials management* (figure 1-3).[9] Waste prevention refers to activities by manufacturers and consumers that avoid the generation of waste in the first place. Examples include using less material to perform the same function (''light-weighting"), or designing durable products so that faulty or obsolete components can be readily replaced, thus extending the product's service life. Better materials management refers to activities that allow product components or materials to be recovered and reused in their highest value-added application. Examples include designing products that can be readily disassembled into constituent materials, or using materials that can be recycled together without the need for separation. These goals should be viewed as complementary: while designers may reduce the quantity of resources used and wastes generated, products and waste streams will still exist and have to be managed.

The idea of green design seems simple, but there is no rigid formula or decision hierarchy for implementing it. One reason is that what is ''green" depends strongly upon context. While some environmental design objectives are sufficiently compel-

[9] This formulation first appeared in U.S. Congress, Office of Technology Assessment, ***Facing America's Trash: What Next for Municipal Solid Waste, OTA-O-424 (Washington*** DC: U.S. Government Printing Office, October 1989).

Figure 1-3-The Dual Goals of Green Design



Green design consists of two complementary goals. Design for waste prevention avoids the generation of waste in the first place; design for better materials management facilitates the handling of products at the end of their service life.

SOURCE: Office of Technology Assessment, 1992.

ling to apply to many different products (e.g., avoiding the use of CFCs), in general OTA expects that green choices will only become clear with respect to specific classes of products or production networks. What constitutes green design may depend on such factors as: the length of product life; product performance, safety, and reliability; toxicity of constituents and available substitutes; specific waste management technologies; and the local conditions under which the product is used and disposed.

Design Tradeoffs

With technologies available to create new materials and to combine conventional materials in new ways, designers are faced with more choices than ever before. One result is that products are becoming more complex and specialized. For example, a typical laundry detergent now contains over 25 different ingredients.

These choices often involve environmental dilemmas. Tradeoffs may be required, not only between traditional design objectives and environmental objectives, but even among environmental objectives themselves-for example, waste prevention versus recyclability.

As an illustration, consider the cross section of a modern snack chip bag depicted schematically in figure 1-4. The combination of extremely thin layers of several different materials produces a lightweight package that meets a variety of needs (e.g., preserving freshness, indicating tampering, and providing product information). The use of so many materials effectively inhibits recycling. On the other hand, the package has waste prevention attributes; it is much lighter than an equivalent package made of a single material and provides a longer shelf life, resulting in less food waste. Even this relatively simple product demonstrates the difficulties of measuring green design.

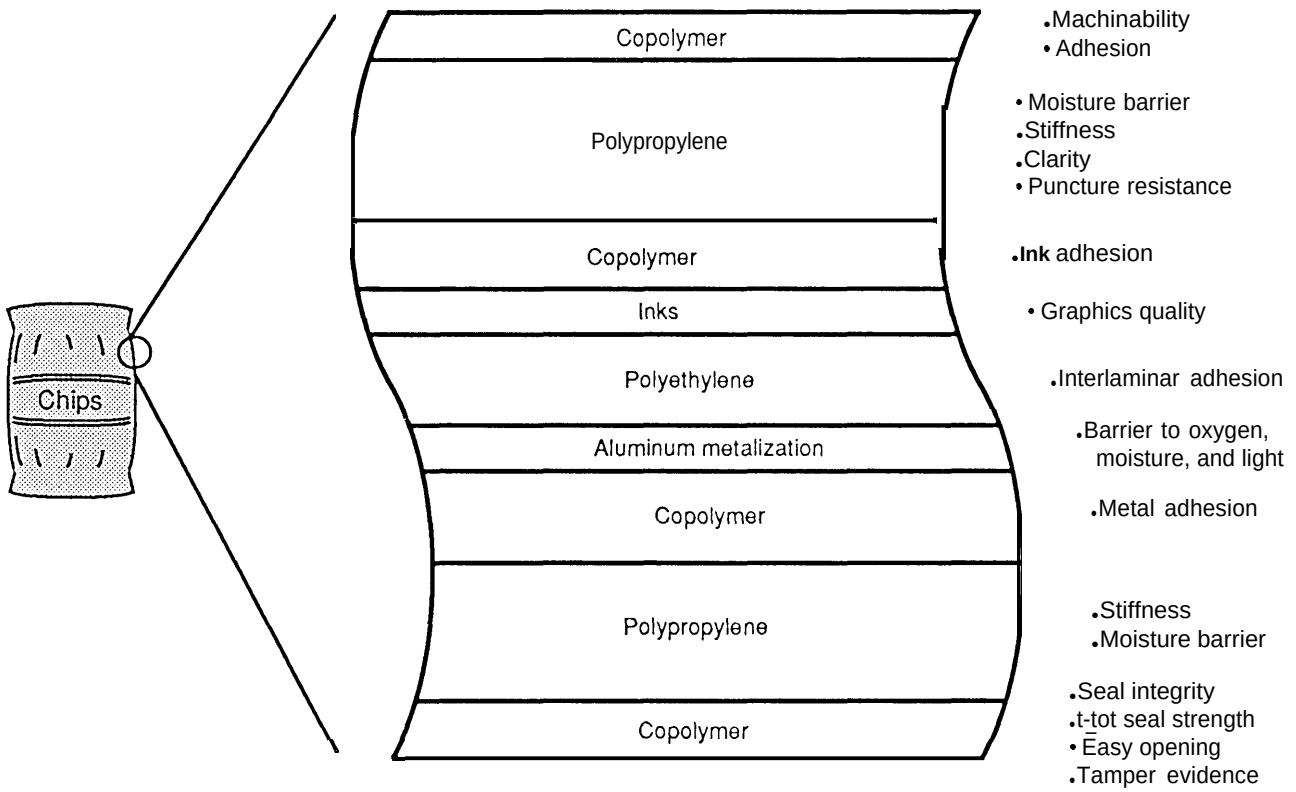
Similar tradeoffs may occur between other attributes, such as energy efficiency and toxicity. For example, energy-efficient, high-temperature superconductors contain a variety of heavy metals, and toxic chemicals are required to manufacture photovoltaic cells. In general, every design will have its own set of environmental pluses and minuses.

Environmental Aspects of Products and Systems

From an environmental point of view, it is simplistic to consider the impact of a product in isolation from the production and consumption systems in which it functions. Is a computer, for instance, a green product? Considered on its own, probably not. The manufacture of a computer requires large volumes of hazardous chemicals and solvents, and heavy metals used in solder, wiring, and display screens are a significant contributor to the heavy metal content of MSW.

But the same computer could be used to increase the efficiency of a manufacturing process, thus avoiding the use of many tons of raw materials and the generation of many tons of wastes. From this perspective, the computer is an enabling technology

Figure 1-4-Cross-Section of a Snack Chip Bag



This cross-section of a snack chip bag illustrates the complexity of modern packaging. The bag is approximately 0.002 inches thick, and consists of nine different layers, each with a specific function. While such complexity can inhibit recycling efforts, it also can reduce the overall weight of the bag, and keep food fresher, thus providing waste prevention benefits.

SOURCE: Council on plastics and Packaging in the Environment.

that reduces the environmental impact of the production system as a whole.

This illustrates an important OTA finding: green design is likely to have its largest impact in the context of changing the overall systems in which products are manufactured, used, and disposed, rather than in changing the composition of products per se. For instance, designing lighter fast-food packaging is well and good; but 80 percent of the waste from a typical fast food restaurant is generated *behind the counter*, where consumers never see it. Addressing this larger problem requires that designers establish cooperative relationships with their suppliers and waste management providers in order to manage materials flows in an environmentally sound way.

There may appear to be few incentives for industry to consider such dramatic changes in existing production networks. After all, longstanding relationships among manufacturers and suppliers may have to change, and millions of dollars maybe invested in the existing infrastructure for production and distribution. Such changes are not generally within the purview of product designers. Indeed, a systems design approach implies the elevation of the product design function to the level of strategic business planning, and a shift in perception by top management in which environmental quality is viewed not as a cost, but as a strategic business opportunity.

But changes of comparable magnitude are already underway. Many manufacturers are rethinking their business relationships with suppliers and customers in order to implement total quality management and concurrent engineering programs. New government regulations in Europe that give manufacturers re-

sponsibility for the environmental fate of their products are also encouraging this approach. For example, Germany's proposed law requiring automakers to take back and recycle automobiles has stimulated the German automobile industry to develop new cooperative strategies for auto design, manufacturing, and recycling (see box l-A).

Policy Implications

These findings have a number of policy implications:

- The environmental evaluation of a product or design should not be based on a single attribute, such as recyclability. Rather, some balancing of pluses and minuses will be required over the entire life cycle.
- The trend toward increasing product complexity seems certain to make the environmental evaluation of products more difficult and expensive in the future.
- Policies to encourage green design should be flexible enough to accommodate the rapid pace of technological change and the broad array of design choices and tradeoffs.
- The biggest environmental gains will likely come from policies that provide incentives for greener production and consumption systems, not just greener products.

GROWING INTEREST IN GREEN DESIGN

The concept of green design is not new. During the 1970s and 1980s, ideas such as design for remanufacturing and design for recycling were developed in technical journals and conferences. At the time, the concept did not receive much attention from policymakers or the public, but green design has enjoyed a renaissance in the past few years. Rising interest among industry groups and design societies around the world is indicated by the proliferation of books, newsletters, and published papers on the subject.

One area of particular interest is the awarding of ''eco-labels' to products that are judged to be environmentally preferred compared with alternative products. Germany, Canada, Japan, the Nordic countries, and the European Community all either have government-funded eco-labeling programs, or will have them in the near future. The United States

Photo credit: Institute of Scrap Recycling Industries, Inc.

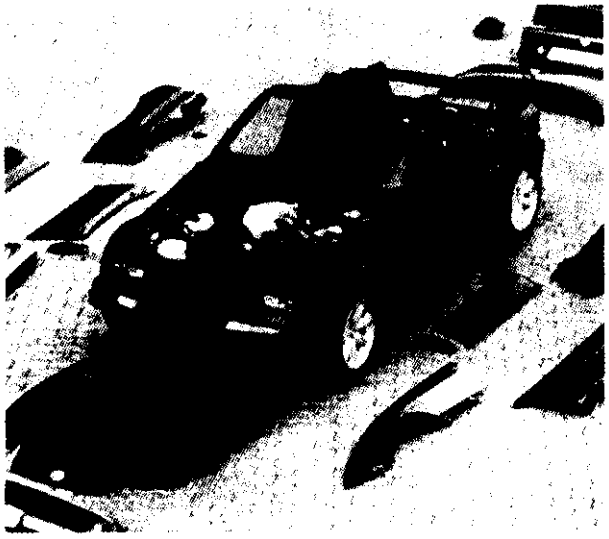


Photo credit: GE Plastics

Top; **When automobile hulks are recycled, most of the metals are recovered. The nonmetal components (plastic, rubber, fabric, and glass) end up as shredder residue that must be landfilled. Bottom: BMW has designed the 21 Roadster so that external body panels and fascia can be easily removed from the automobile frame and subsequently recycled.**

Box 1-A—Design and Materials Management in the Auto Industry

When an old car is junked, it is often first sent to a dismantler, who removes any parts that can be resold, as well as the battery, tires, gas tank, and operating fluids. The hulk is then crushed and sent to a shredder, which tears it into fist-sized chunks that are subsequently separated to recover the ferrous and nonferrous metals.

Presently, about 75 percent by weight of materials in old automobiles (including most of the metals) are recovered and recycled. The remaining 25 percent of the shredder output, consisting of one-third plastics (typically around 220 pounds of 20 different types), one-third rubber and other elastomers, and one-third glass, fibers, and fluids, is generally landfilled. In the United States, this shredder "fluff" amounts to about 1 percent of total municipal solid waste. Sometimes, the fluff is contaminated with heavy metals and oils, or other hazardous materials.

As automakers continue to search for ways to improve fuel efficiency and reduce manufacturing costs, the plastic content of cars is expected to increase. This will not only increase the amount of shredder fluff sent to landfills, it threatens the profitability of shredder facilities, which currently depend on metals recovery to make money.

In Germany, the landfilling of old automobile hulks and the shredder residues from automobile recycling operations is a growing problem. The German Government has proposed legislation that would require automakers to take back and recycle old automobiles at the end of their lifetime. This has stimulated German automakers to explore fundamental changes in automobile design that could result in more efficient materials management. These changes would involve new relationships among auto manufacturers, dismantlers, and materials suppliers.

To avoid dealing with the auto hulks themselves, the automakers propose to take better advantage of the existing infrastructure for auto recycling. Manufacturers will design cars that can be more cheaply disassembled, and will educate dismantlers on how to efficiently remove plastic parts. They will encourage their material suppliers to accept recovered materials from dismantlers, and will specify the use of recovered materials in new car parts, thus "closing the loop."

Green automobile design within this new framework of coordinated materials management has a very different character than auto design within an isolated firm. Instead of just thinking about how to design a fender or bumper using 10 percent less material, the designer also thinks about how the fender or bumper can be constructed from materials that can be co-recycled, and readily separated from the car body.

Several German companies, including BMW and Volkswagen, have begun to explore this system-oriented approach. BMW recently built a pilot plant in Bavaria to study disassembly and recycling of recovered materials, and Volkswagen AG has constructed a similar facility. The goal of the BMW facility is to learn to make an automobile out of 100 percent reusable/recyclable parts by the year 2000. In 1991, BMW introduced a two-seat roadster model with plastic body panels designed for disassembly and labeled as to resin type so they may be collected for recycling.

Interest in improving materials management in the auto industry is not limited to Europe. Japan's Nissan Motor Co. has announced research programs to explore design for disassembly, to reduce the number of different plastics used, to label those plastics to facilitate recycling, and to use more recovered materials in new cars. In the United States, Ford, Chrysler, and General Motors plan to label plastic components to identify the polymers, and have recently established a consortium with suppliers and recyclers (called the Vehicle Recycling Partnership) to address the recycling issue.

Autos are already one of the most highly recycled products in the United States. This success is largely due to the efficiency of shredder technology; a single facility can process up to 1,500 hulks per day. This level of productivity is not consistent with labor-intensive disassembly operations. Although research on recycling automotive plastics is ongoing, it is not yet economically feasible to separate and recycle these materials, even when avoided landfill tipping fees are included. Thus, it seems clear that a change in materials management in the U.S. auto industry is unlikely to emerge without substantial new economic or regulatory incentives.

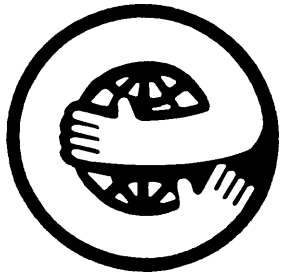
SOURCE: Office of Technology Assessment, 1992.

Figure 1-5--Eco-labels Around t he World

Canada (Environmental Choice)

Nordic Countries (White Swan)

West Germany (Blue Angel)



Japan (EcoMark)

United States (Scientific Certification Systems)*

United States (Green Seal)

Eco-labels are intended to identify environmentally preferred products for consumers. Above are government-sponsored labels from four foreign programs and two private U.S. labels.

***NOTE:** The SCS label will provide comparative data on environmental attributes (see figure 4-l).*

has no national program, but two private labeling efforts are underway (figure 1-5).

Product packaging, perhaps the most visible component of the post-consumer waste stream, continues to be the target of control measures that include bans, taxes, deposits, and recycling requirements. One of the most dramatic initiatives is Germany's Packaging Waste Law, which gives manufacturers and distributors the responsibility for recovering and recycling their own packaging wastes. In fact, the idea of shifting the burden of dealing with discarded products from municipalities to manufacturers appears to be gaining momentum in Europe, and may soon be extended to durable goods, such as household appliances and automobiles. This statutory coupling of manufacturing with post-consumer recycling is forcing manufacturers—including U.S.-based manufacturers with subsidiaries in Europe—to change the way they design products.

The European Community is wrestling with the problem of harmonizing the different environmental product standards and recycling laws of member countries with the approach of the Single Market in 1992. These laws have proved contentious in the past, and harmonization is not yet in sight. Recent controversies over whether countries can restrict imports of goods deemed harmful to health or the environment, or whether such restrictions constitute nontariff barriers to trade, suggest that the harmonization of international environmental product policies is becoming a thorny problem that will have to be resolved in future negotiations under the General Agreement on Tariffs and Trade (GATT') and other international agreements.[10]

Many States within the United States are also enacting policies aimed at reducing the environmental impacts of products. These measures include mandating industry plans to reduce their use of toxic chemicals, mandating the disclosure of the use of hazardous chemicals in products, and establishing standard definitions for advertisers' use of terms like "recycled." States have also enacted some targeted product control measures such as recycled content requirements for newspaper, bans and taxes on specific packages, mandated manufacturer take-back of batteries, and tax incentives for recycling. The lack of uniform Federal environmental standards for products is alarming to industry, which fears having to satisfy 50 different State regulations. This prospect is especially of concern for products distributed through national networks.

10 For an overview of the issues, see the U.S. Congress, Office of Technology Assessment *Trade and Environment: Conflicts and Opportunities*, OTA-BP-ITE-94 (Washington DC: U.S. Government Printing Office, May 1992).

The United States cannot be said to be "behind" other countries in the development of environmental policies that encourage green product design. Indeed, many European countries look enviously at U.S. environmental policies such as auto emissions standards, or the timetable for phaseout of CFC production and use, which are among the most aggressive in the world. Some U.S. chemical companies are acknowledged world leaders in waste prevention techniques.

It is more accurate to say that the U.S. approach differs substantially from the approaches being taken abroad, and these differences could create conflicts in the future. Whereas some of the 'greener' European countries (especially Germany, the Netherlands, and the Nordic countries) increasingly focus on the environmental attributes of products at the national level, U.S. policies continue to focus on regulating industrial waste streams. Except in cases where products pose a clear threat to human health (e.g., some pesticides, PCBs, leaded gasoline and paint), the Federal Government has been reluctant to regulate the environmental attributes of products directly. For example, the Resource Conservation and Recovery Act regulates ''hazardous" industrial waste closely, but delegates the primary responsibility for product disposal and ''non-hazardous" solid waste management to the States.[11]

OTA finds no compelling reason for U.S. policies to necessarily imitate the product control policies in Germany or other countries (although monitoring the implementation of these initiatives could provide valuable lessons for the United States). In fact, many observers believe that some of the more extreme measures, such as Germany's mandatory take-back provisions for packaging waste, will prove to be costly and difficult to implement.

Nevertheless, the rapid evolution of environmental product policy, both in the States and abroad, suggests that the Federal Government needs to become more strongly involved for two reasons: 1) to keep abreast of technology and policy developments, and 2) to help shape policies that reduce barriers to interstate commerce and international trade. Options for greater Federal involvement are discussed below.

SHAPING ENVIRONMENTAL POLICIES THAT ENCOURAGE GREEN DESIGN

Some U.S. companies argue that existing market forces and environmental regulations are sufficient to encourage green design. They tend to view new environmental constraints on the design of products as a threat to their competitiveness and a drag on economic growth, especially during an economic recession. These companies are reluctant to redesign established products to achieve environmental benefits that have little value or visibility to their customers.

In fact, companies already have a number of incentives to move toward green design. By reducing the quantity of materials used in products, they can reduce manufacturing costs; by reducing the hazardous material content of products, they can reduce the rising costs of pollution control, waste disposal, and potential liability. There are also opportunities to gain consumer loyalty by enhancing the environmental attributes of their products. These incentives are already having an effect on the way many companies do business: for example, less toxic substitutes for heavy metals are being adopted in such products as inks, paints, and batteries; environmental advertising is being used to sell a range of products from gasoline to fabric softener; and more and more companies have recognized the linkages between improved product quality and improved environmental quality.

Even if Congress takes no further action, these incentives can be expected to continue in the future. For example, as permitted landfill capacity continues to shrink, waste disposal costs should increase, providing companies with greater incentives to reduce their wastes. Implementation of tougher emissions standards under the Clean Air Act Amendments of 1990 will increase pressures on companies to reduce their use of hazardous solvents and other volatile organic compounds. Various States will no doubt continue to pass legislation to regulate the environmental attributes of products and waste streams. And as consumers become more attuned to environmental concerns, they will increasingly de-

[11] However, the RCRA reauthorization debate has involved a number of new proposals that would establish national requirements for product design, including mandatory recycled content, reduced toxic chemical content and government procurement of recycled products.

Photo credit: "Selling Green. " Copyright 1991 by Consumers Union of U. S., Inc., Yonkers, NY 10703-1057. Repnntedbypermission from CONSUMER REPORTS, October 1991.

This collage of fictional packages illustrates the trend toward environmental marketing.

mand that manufacturers take more responsibility for the environmental impacts of their products.

But OTA finds that there are four specific areas of need that existing market forces or regulations do not adequately address, and that are uniquely the responsibility of the Federal Government:

- *Research—At* present, policymakers don't know what materials or waste streams are of greatest concern, or about how product designs might be changed to address them most effectively. Private companies have no incentive to conduct this research.
- *Credible information for consumers-Surveys* show that consumers are interested in green products, but most don't know what is 'green.' As discussed above, defining what's green is a multidimensional problem. In the absence of Federal action to establish consistent ground rules defining terms and measurement methods, the growing interest of consumers could become dissipated in confusion and skepticism.
- *Market distortions and environmental externalities—Despite the* existing incentives for green design noted above, critics of present consumption patterns argue that important market distortions and environmental externalities remain that encourage inefficient use of materials and energy. Failure to internalize these environmental costs into design and production decisions can make environmentally sound choices seem economically unattractive.
- *Coordination and harmonization-OTA* found that several research projects related to green design are being sponsored by various Federal agencies and offices, but that there is little or no coordination among them. And unlike its major competitors, the United States has no institutional focus at a national level for addressing environmental product policy.

Current Federal Efforts Related to Green Design

OTA identified a number of ongoing Federal activities that partially address these needs (table l-l). EPA is most directly involved. For example, its Office of Research and Development has several projects underway to develop generic guidelines for green design. However, there are relevant projects scattered through several other agencies, including the Department of Energy (DOE) and the National Science Foundation.

Several recent initiatives could help to remove some of the barriers to green design that exist in current Federal rules and regulations. In October 1991, President George Bush signed Executive Order 12780, the Federal Recycling and Procurement Policy, which requires Federal agencies to increase recycling and waste reduction efforts, and to encourage markets for recovered materials by favoring the purchase of products with recycled content. The Department of Defense has issued recent directives emphasizing waste prevention through the acquisition process and through military specifications and standards. Some 40,000 military specifications requiring the use of hazardous materials are currently under review. These initiatives will help to create markets for green products.

There are also several ongoing activities that could improve the quality of information available to consumers and citizen groups. EPA and the Federal Trade Commission (FTC) are developing guidelines for advertisers' use of environmental terms such as "recycled." National standards for use of these terms in advertising can give consumers confidence that a product advertised as "source-reduced" or ''recycled' is really better for the environment. In the Pollution Prevention Act of

Table I-I—Federally Funded Programs Related to Green Design

Agency/office	Program/activity	Comments
Department of Energy		
Office of Industrial Technologies	Industrial Waste Reduction Program	This research and development program aims to identify priority industrial waste streams, assess opportunities for addressing these waste streams through redesigning products and production processes, and technology transfer from national laboratories.
Environmental Protection Agency		
Office of Research and Development	Environmental Resource Guide	Contracted to the American Institute of Architects, this project will provide information to architects on the life-cycle environmental impacts of instruction materials.
	Dynamic Case Studies on Environmentally Advanced Product Design	Contracted to the Resource Policy Institute in Los Angeles and the Product Life institute in Geneva, this project will explore case studies involving green product design.
	Life Cycle Assessment Methodology	Contracted to Battelle, this project will develop standard methodologies for conducting product life-cycle assessments.
	Clean Products Case Studies	Contracted to INFORM Inc., this project will provide case studies of green design, especially the reduced use of toxic substances in products.
	Safe Substitutes	Contracted to the University of Tennessee, this project will identify priority toxic chemicals and evaluate possible substitutes.
	Life Cycle Design Guidance Manual: Environmental Requirements and the Product System	Contracted to the University of Michigan, this manual will explore how designers can incorporate life-cycle information into their designs.
	National Pollution Prevention Center	Located at the University of Michigan, this center is developing waste prevention information modules for industrial and engineering design courses.
	American Institute for Pollution Prevention	in association with the University of Cincinnati, the institute serves as a liaison to a broad cross-section of industry, with projects involving four aspects of waste prevention: education, economics, implementation, and technology.
Office of Pollution Prevention and Toxics	Design for the Environment	Proposed program to gather, coordinate, and disseminate information on green design.
National Science Foundation	Engineering Design Research Center	Located at Carnegie Mellon University, the center is organizing a program to explore methods for green design.

SOURCE: Office of Technology Assessment.

1990, Congress required manufacturers who report their releases of toxic chemicals for the Toxic Release Inventory (TRI)[12] to also report how these releases were affected by product and process redesign. When this provision is implemented, it could become a valuable source of information in an area where little information currently exists: how product design choices affect industrial waste streams.

In the short term, Congress can make a good start toward encouraging green design by using its oversight powers to ensure that these ongoing activities are carried through to their conclusion, and **that the** provisions of the Pollution Prevention Act are implemented expeditiously.

Long-Term Options

In the longer term, Congress may wish to address the needs identified above more directly. These needs are discussed in greater detail below.

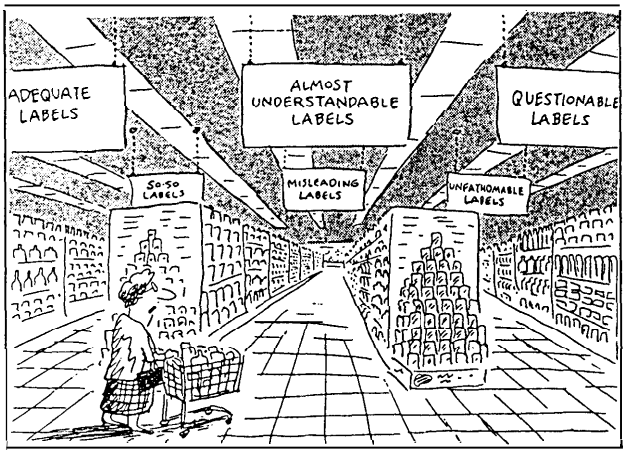
Research

Of critical importance is to identify what materials and products pose the greatest risks to human health and the environment. Without this information, Congress cannot intelligently set priorities for

12 As required under Title III of the Superfund Amendments and Reauthorization Act of 1986.

environmental policy. Congress could direct EPA and DOE to identify a short list of priority materials, products, and waste streams; identify areas where additional data are needed to assess their health and environmental impacts; and develop quantitative models showing how these high-risk materials flow through the economy.

Research is also needed to develop techniques for measuring the environmental impact of products and systems, to better understand how the business climate and corporate culture affect product design decisions vis-a-vis the environment, and to explore the costs and benefits of various policy options such as manufacturer take-back requirements.



Credit: Wayne *Stayskal, Tampa Tribune*

Credible Information for Consumers

As discussed above, national standard definitions for advertisers' use of environmental terms could alleviate consumer confusion associated with current environmental claims. An important goal for the future will be to determine how to credit products that feature waste prevention in regulations and government procurement programs that are currently focused on recycling and recycled content. For example, should waste prevention be measured with respect to waste generated in some previous base year, or with respect to other comparable products in the current year?

The United States has two small, private eco-labeling efforts underway. One potential concern is that a variety of private labels based on different appraisal methods could lead to confusion about which products are actually better for the environment. To address this problem, Congress could designate EPA to develop standards for the certification of private eco-labeling programs. This might give consumers confidence that products carrying certified eco-labels are in fact better for the environment. Alternatively, it could appoint a blue-ribbon commission to oversee the establishment of an independent, national eco-labeling program similar to those of other countries.

Where the disclosure of public information on industrial waste streams has been mandated by Congress, e.g., through the Toxic Release Inventory, this has proven to be a powerful motivation for companies to change their designs and manufacturing processes. Expanded industry reporting requirements under TRI could improve the information on materials flows available to public interest groups and ultimately to consumers. This might involve expanding the number of reportable chemicals, the types of industries required to report, or expanding reporting requirements themselves to include the actual *use* of priority chemicals in products and processes, not just the *release* of these chemicals to the environment. However, unless these requirements are narrowly targeted on chemicals or materials of special concern (see research needs above), they would significantly increase industry's reporting costs, and might not result in a commensurate reduction of environmental risk.

Market Distortions and Environmental Externalities

Products have environmental impacts at every stage of their life cycle. Yet, many of these are not accounted for in the prices of materials and products. On the production side, there are government subsidies or special tax treatment for the extraction of virgin materials (e.g., below-cost timber sales and mineral depletion allowances), and many "non-hazardous" industrial solid wastes (e.g., mine tailings or manufacturing wastes that are managed on-site) with significant environmental impacts are not regulated at the Federal level. On the consumption side, consumers often do not pay the full environmental costs of products that are consumed or dissipated during use (e.g., gasoline, cleaners, agricultural chemicals), or the full cost of solid waste disposal.

Table 1-2 presents a menu of regulatory and market-based incentives that have been proposed to address environmental problems associated with the flow of goods and materials through the economy.

Table 1-2—Policy Options That Could Affect Materials Flows

Life-cycle stage	Regulatory instruments	Economic instruments
Raw material extraction and processing	Regulate mining, oil, and gas non-hazardous solid wastes under the Resource Conservation and Recovery Act (RCRA). Establish depletion quotas on extraction and import of virgin materials.	Eliminate special tax treatment for extraction of virgin materials, and subsidies for agriculture. Tax the production of virgin materials.
Manufacturing	Tighten regulations under Clean Air Act, Clean Water Act, and RCRA. Regulate non-hazardous industrial waste under RCRA. Mandate disclosure of toxic materials use. Raise Corporate Average Fuel Economy Standards for automobiles. Mandate recycled content in products. Mandate manufacturer take-back and recycling of products. Regulate product composition, e.g., volatile organic compounds or heavy metals. Establish requirements for product reuse, recyclability, or biodegradability. Ban or phase out hazardous chemicals. Mandate toxic use reduction.	Tax industrial emissions, effluents, and hazardous wastes. Establish tradable emissions permits. Tax the carbon content of fuels. Establish tradable recycling credits. Tax the use of virgin toxic materials. Create tax credits for use of recycled materials. Establish a grant fund for clean technology research.
Purchase, use, and disposal	Mandate consumer separation of materials for recycling.	Establish weight/volume-based waste disposal fees. Tax hazardous or hard-to-dispose products. Establish a deposit-refund system for packaging or hazardous products. Establish a fee/rebate system based on a product's energy efficiency. Tax gasoline.
Waste management	Tighten regulation of waste management facilities under RCRA. Ban disposal of hazardous products in landfills and incinerators. Mandate recycling diversion rates for various materials. Exempt recyclers of hazardous wastes from RCRA Subtitle C. Establish a moratorium on construction of new landfills and incinerators.	Tax emissions or effluents from waste management facilities. Establish surcharges on wastes delivered to landfills or incinerators.

SOURCE: Office of Technology Assessment.

These options are organized according to their point of greatest impact in the product life cycle. Each could have an impact on product design, but an analysis of the design implications of these options is beyond the scope of this report. However, OTA offers three guiding principles that policymakers should consider as they evaluate these options (see below).

Coordination and Harmonization

Green design is. a multidisciplinary subject that does not fit comfortably within the mission of any single Federal agency. For instance, EPA is organized around regulatory responsibilities for protecting air, water, and land; its technical expertise in design and manufacturing areas is slight. The Department of Commerce (DOC), on the other hand, is concerned with the competitiveness of industrial sectors, but has little environmental expertise. DOE's national labs have considerable experience that could be brought to bear on improving the efficiency of industrial energy use and waste prevention, but environmental quality has not traditionally been a part of DOE's mission. The story is much the same with other agencies.

As described here, green design refers not to a rigid set of product attributes, but rather to a decision process whose objectives depend upon the specific environmental problems to be addressed. This suggests that the most meaningful way in which the Federal Government can encourage green design is through multiagency initiatives organized around particular environmental problems, policy issues, or industrial sectors. These collaborations are beginning to be formed on an ad hoc basis. For instance, EPA is working with the Department of Agriculture to promote waste preven-

tion in agricultural chemical use. EPA, DOE, and DOC are collaborating in a joint grant program with States to fund research on reducing the environmental impacts of industrial processes.[13] These efforts are a start; however, much more could be done in the following areas:

- *Promoting information* exchange-Current mechanisms for disseminating information on relevant research activities in various agencies are only partially effective. A central repository containing information on all relevant Federal research activities would be helpful.
- *Promoting system-oriented design solutions*—A greener transportation sector, for example, may involve not only improved vehicle fuel efficiency, but better management of materials used in automotive, rail, aviation, etc., as well as changes in urban design. A multiagency perspective could provide a more holistic analysis of total sectoral issues, through forums, grant programs, etc.
- *Harmonizing State and Federal environmental product policies—Policy* guidance is needed to help define the circumstances under which Federal standards preempting State and local product control laws may be justified, and where they are not.
- *Coordinating policy development on international aspects of the environment, U.S. competitiveness, trade, and technology--At* present, responsibility for development of U.S. policy in these areas is not clearly defined, with each Federal agency having its own agenda.

To address these needs, Congress could:

- Provide funding for a central electronic network listing current Federal research projects, case studies, and bibliographic materials relating to green design.
- Use its oversight powers to clarify which agencies have lead responsibility for policy development on interstate and international aspects of U.S. environmental product policy.
- Ensure that green design considerations are integrated into the charter of any new environmental or technological organizations now being proposed before Congress, such as the National Institutes for the Environment or a Civilian Technology Agency.

In the end, the institutional details are less important than a recognition on the part of Congress and the Administration that Federal leadership is needed to take advantage of opportunities such as green design that do not fall neatly within the mission of any single agency.

GUIDING PRINCIPLES FOR POLICY DEVELOPMENT

The discussion above suggests three general principles that Congress can use to develop environmental policies that encourage, rather than inhibit, green design.

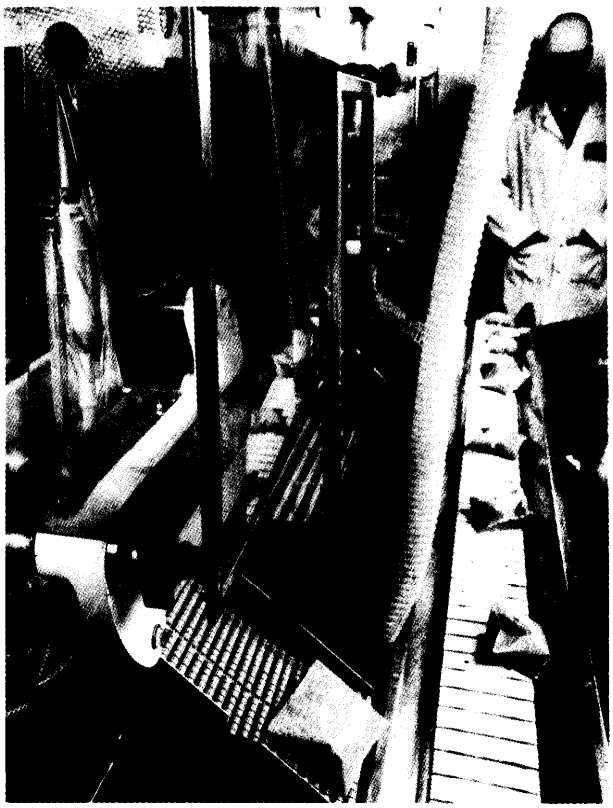
Principle 1: Identify the root problem and define it clearly.

One of the biggest challenges in selecting a policy strategy is clearly defining the problem to be addressed. One difficulty is that products and waste streams have multiple environmental impacts that cannot be easily disentangled. Policymakers may be concerned with the quantity of a particular waste stream, its toxicity, or persistence in the environment. Policies aimed at solving one problem may have unintended negative effects on another; for example, requiring automobiles to be made from currently recyclable materials could adversely affect their fuel efficiency. Inevitably, tradeoffs and value judgments must be made as to which environmental impacts are the most important.

Disagreements about how to define the environmental problem may also reflect more fundamental philosophical differences. Industry tends to frame the problem in terms of reducing the quantity of waste destined for disposal, while environmental groups often focus on threats to natural resources and ecological "sustainability." These different problem statements lead to different policy prescriptions and different ideas about what constitutes green design. Clearly defining the problem to be addressed can help to elevate the level of debate and to identify possible areas of compromise.

In the absence of a clearly defined problem, it becomes easy to confuse means and ends. Proxies for environmental quality, such as recycling, can come to be perceived as ends in themselves, rather than as one of several strategies for reducing solid

13 The program is called National Industrial Competitiveness through Efficiency: Energy, Environment, Economics (NICE³).



waste. By mandating that products and packaging contain a minimum recycled content, for instance, Congress would certainly encourage product designers to use recovered materials in packaging; but this would not necessarily result in less waste overall. Perversely, this could even lead to more waste, especially if designs featuring waste prevention are thereby discouraged. If the objective is to reduce the amount of solid waste generated, MSW policies and government procurement programs should make allowances for product designs that feature waste prevention.

Defining the problem properly must entail some consideration of environmental risks. OTA finds that policymakers currently lack critical information on how materials flow through the economy and about the relative risks of different materials and products. For example, 10 States have passed legislation banning the use of heavy metals in packaging, even though this source contributes only 4 to 7 percent of heavy metals in landfills and incinerators. Without research to develop information on materials flows and relative risks, resources are likely to be directed toward the most visible

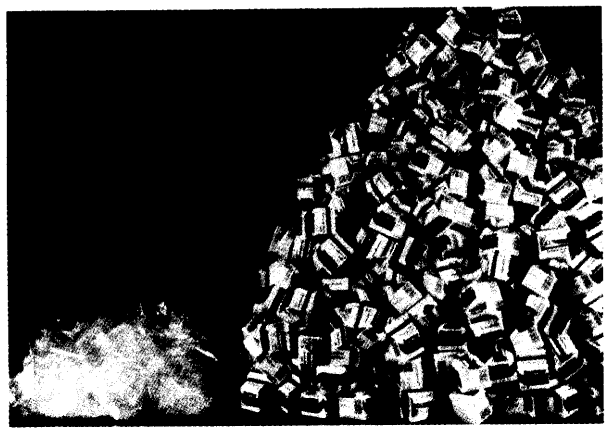


Photo credit: Dupont Magazine (July/August 1991)

A thin plastic milk pouch uses less material than a traditional paperboard carton, and takes up less space in a landfill.

problems, rather than those that pose the greatest environmental risks.

Principle 2: Give designers the maximum flexibility that is consistent with solving the problem.

Materials technology options are proliferating rapidly, and product impacts on the environment are nearly always multidimensional. Policies should be crafted to give designers as much flexibility as possible to find the best solutions, within a framework that protects human health and the environment. Rigid Federal mandates that impose predetermined design solutions (such as bans on the use of certain materials) are likely to be inefficient, and should be avoided if possible. Flexibility can be achieved through a variety of means, including flexible regulations, economic instruments, and negotiated voluntary agreements with industry.

One tradeoff for increasing policy flexibility is likely to be increased costs of policy monitoring and enforcement. For example, verifying compliance with a ban on the use of a given material or chemical requires less information than verifying compliance with voluntary agreements or flexible regulations. For this more flexible approach to work, the cost of demonstrating compliance will probably have to be borne by industry.

Principle 3: Encourage a systems approach to green design.

If policymakers focus exclusively on addressing the environmental attributes of products, as opposed to the systems in which products are manufactured, used, and disposed, they are likely to miss the biggest opportunities for green design.

A system-oriented design approach can be encouraged either directly by regulation, or indirectly through economic incentives. Recycled content regulations or manufacturer take-back requirements are examples of a regulatory coupling between manufacturing and waste management. The proposal of the German Government to require auto manufacturers to take back and recycle their cars, for example, has stimulated the German automakers to rethink the entire ‘‘ecology’ of auto production and disposal (box l-A). This approach may be more appropriate for high-value, durable products than for nondurable or disposable products.

An alternative to take-back regulations is to indirectly encourage designers to take a systems approach by using economic instruments to internalize the costs of environmental services. This approach would rely on market forces to sort out what new interfirm relationships make sense economically, while giving designers the flexibility to design products with the best combination of cost, performance, and least environmental impact. For example, a substantial carbon tax on fuels could have a dramatic impact on the systems by which products are manufactured, distributed, and disposed, because fuels are consumed at every stage of the product life cycle.

CONCLUSION

Green product design offers a new way of addressing environmental problems. By recasting pollution concerns as product design challenges, and particularly by encouraging designers to think more broadly about production and consumption systems, policymakers can address environmental problems in ways that would not have been apparent from a narrow focus on waste streams alone.

The flow of materials and products through the world economy has a critical influence on both economic growth and the environment. These flows are determined in part by design decisions. Therefore, policymakers should strive to make green product design an integral part of strategies to improve competitiveness and environmental quality. OTA’s analysis suggests that simply providing information to designers and consumers about the environmental impacts of products and waste streams is not enough. To move ahead, the environmental costs of production, consumption, and disposal should be accounted for at each stage of the product life cycle. The challenge to policymakers is to choose a mix of regulatory and economic instruments that target the right problems and give designers the flexibility to find innovative, environmentally elegant solutions.