

**Economic Issues in the Reuse of Automotive Plastics**

December, 1993

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Prepared for the  
Automotive Plastics Recycling Project

Report Number: UMTRI: 93-40-2

## Preface

The Office for the Study of Automotive Transportation (OSAT), in cooperation with researchers from other units of the University of Michigan, is undertaking a multiyear program of research titled "Effective Resource Management and the Automobile of the Future." The first project focused on recycling automotive plastics and provides an independent evaluation and review of the issues and challenges that recycling pose for this class of materials.

The Automotive Recycling Project benefited from the financial support of numerous sponsors: The American Plastics Council; The Geon Company; Hoechst Celanese; Miles, Inc.; OSAT's Affiliate Program; Owens-Corning Fiberglas; and The University's Office of the Vice President for Research. In addition, representatives of each of the Big Three automakers graciously served on the Project's advisory board, as did Suzanne M. Cole.

The project reports provide an overview and analysis of the resource conservation problems and opportunities involved in the use of plastics, and describes the factors that are likely to influence the future of automotive plastics. We develop information on the economic, infrastructure, and policy aspects of these issues, identifying the barriers to and facilitators of automotive plastics use that is less constrained by resource conservation and recycling concerns. At the same time, the Vehicle Recycling Partnership, a precompetitive joint research activity of the Big Three, is devoting its resources to the technical issues raised by recycling automotive plastics.

The Recycling Automotive Plastics project yielded six reports:

Life Cycle Assessment: Issues for the Automotive Plastics Industry (UMTRI Report #90-40-1), by Brett C. Smith and Michael S. Flynn, an overview of the LCA approach and its implications for automotive plastics (15 pages). This paper includes, as an appendix, the EPA design manual by Greg Keoleian and Dan Menerey, *Life Cycle Design Manual: Environmental Requirements and the Product System*;

Economic Issues in the Reuse of Automotive Plastics (UMTRI Report #90-40-2), by Daniel Kaplan, a general consideration of the economic barriers and issues posed by recycling automotive plastics (42 pages);

Recycling the Automobile: A Legislative and Regulatory Preview (UMTRI Report #90-40-3), by Suzanne M. Cole, Chair, Society of Plastic Engineers, International Recycling Division, describes the likely developments on the federal regulatory and legislative front that will influence the future of automotive plastics use and disposition (26 pages);

Postconsumer Disposition of the Automobile (UMTRI Report #90-40-4), by T. David Gillespie, Daniel Kaplan, and Michael S. Flynn, a review of the issues and challenges over the different disposal stages posed by postconsumer automotive plastics (54 pages);

Material Selection Processes in the Automotive Industry (UMTRI Report #90-40-5), by David J. Andrea and Wesley R. Brown, an overview of the factors and issues in vehicle manufacturers' material selection decisions (34 pages);

Automotive Plastics Chain: Some Issues and Challenges (UMTRI Report #90-40-6), by Michael S. Flynn and Brett C. Smith, a report of the OSAT survey of the automotive plastics industry (27 pages), plus appendix on types of automotive plastics.

These reports are all available from:

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**Executive Summary:  
Recycling Automotive Plastics**

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The Recycling Automotive Plastics project provides an overview and analysis of the resource conservation problems and opportunities involved in the automotive use of plastics and composites, and describes the factors that are likely to influence their future. The project produced a series of six reports targeted to different aspects of the recycling challenges posed by automotive plastics. Combined with the technically oriented reports of the Vehicle Recycling Partnership, these reports should serve two purposes. First, they can serve as a broad introduction to the diverse and numerous dimensions of the recycling challenge for automotive managers whose areas of responsibility only indirectly or peripherally touch on recycling. Second, they can provide specialists with a broad panoply of contextual information, anchoring their detailed knowledge within the broad framework of recycling issues.

Automotive plastics possess numerous advantages for the automotive manufacturer and consumer. They contribute to lower vehicle weight, important for fuel conservation and emission reduction, while permitting the additional weight of new safety equipment. Plastics and composites are corrosion resistant, so their use can prolong vehicle life, and they are an important element in the paints used to protect other materials. They offer the designer greater flexibility, reducing the constraints that other materials often impose on shapes and packaging. If the difficulties of recycling automotive plastics present a potential barrier to their use, their advantages suggest that the barrier should be overcome, rather than deterring their continued automotive applications.

However, automotive plastics are visible and easily tied to the vehicle manufacturers. Hence, they may become targets for public opinion and government action out of proportion to their real role in solid waste disposal issues and potential for economic recycling.

I. The first report (Life Cycle Assessment: Issues for the Automotive Plastics Industry, UMTRI Report #90-40-1, by Brett C. Smith and Michael S. Flynn) provides an overview of the developing Life Cycle Assessment (LCA) approach and its implications for automotive plastics. An element of the emerging “design for the environment” method, LCA calls for an inventory,

impact assessment, and improvement analysis targeted to the environmental consequences of a product across its production, use, and retirement. While environmental costs are typically unavailable, LCA supports the inclusion and consideration of any such costs that can be estimated, particularly for some of the environmental factors often ignored in traditional product decisions.

A fully developed LCA for vehicles or even components presents numerous significant analytic challenges to the industry, and may never become practical. First, a full LCA would be extremely costly, and the human and financial resources it would consume may be simply unavailable. Second, the handling of the data in an LCA can critically determine its outcome. The data for factors in an LCA are often lacking, typically measured in different metrics, subject to variable weightings, and frequently aggregated in different, noncomparable ways. Third, LCAs are difficult to evaluate and compare because they often reflect differing assumptions, varying boundaries, and there are no commonly accepted standards for their execution. Finally, the comparison of environmental costs with more traditional cost factors is at best difficult and speculative.

Nevertheless, LCA offers industry a sensitizing tool, useful for ensuring consideration of some environmental effects, and consistent with an industrial ecology approach to resource conservation. Moreover, the LCA approach resonates with some other developments in the automotive industry. Thus the industry is moving to more system-based material decisions, while its accounting system is evolving to a form that would more readily provide input for an LCA. The growing emphasis on cost reduction and waste elimination is also philosophically consistent with LCA goals. The industry has gained experience in other analytic techniques, such as quality function deployment, that have value even if only partially executed.

The automotive industry must shift from a reactive to a proactive approach in the management of its environmental effects. The ability to move quickly and surely to develop environmentally acceptable products and processes will be critical to future success. Establishing environmental credibility will increasingly afford the manufacturers an opportunity to create a positive image and thus a competitive edge in the marketplace. LCA might become an important tool in the development of an environmentally friendly product. However, cost pressures in today's competitive environment will likely make the industry approach environmental issues in a cautious manner.

II. The second report (Economic Issues in the Reuse of Automotive Plastics, UMTRI Report #90-40-2, by Daniel Kaplan) presents a general consideration of the economic barriers and issues posed by recycling automotive plastics. The United States currently recycles roughly 75% of the automobile, although plastics constitute roughly one-third by weight of the landfilled residue. An important question facing the automotive plastics industry is whether a combination of economic and technical developments might occur that would permit plastics to repeat the recycling success story of automotive steel.

Recycling automotive plastics faces two major economic barriers. First, the labor cost to recover the materials in usable form is quite high, making it unlikely that recycled stock can compete with the price of virgin stock. The second is that recyclers cannot rely on a consistent and stable flow of plastic scrap, as retired automobiles vary greatly in the level and type of plastic content. This makes it difficult, if not impossible, to establish end markets. Other economic barriers to successful recycling include the costs of transportation and recovery.

There are nonrecycling options for automotive plastics disposal. The landfill option still exists, although current trends suggest that it may soon become expensive enough to promote the use of other options, such as pyrolysis. Incineration permits energy recovery, but faces some of the same undesirable side-effects as landfills.

Pressure for recycling may raise the likelihood of policy interventions, as the government tries to avert the negative consequences of automotive plastics content, such as landfilling, while preserving its benefits, such as reduced fuel consumption and vehicle emissions. Government efforts will likely focus on attempts to capture the environmental externalities in the price of materials. However, recycling may have an economic down side: at least some automotive plastics, if fully recycled, could damage the viability of both recyclers and resin producers by creating an oversupply of material.

The numerous policy tools that might be invoked by government have a predictably wide range of consequences, and these must be incorporated into a cost-benefit analysis before appropriate selections can be implemented. In any case, the industry must be prepared to respond to a wide range of possible policy developments that will shape the economic viability of recycling.

III. The third report (Recycling the Automobile: A Legislative and Regulatory Preview, UMTRI Report #90-40-3, by Suzanne M. Cole) describes the likely developments on the federal regulatory and legislative front that will influence the future of automotive plastics use and disposition. Public policy often tries to incorporate social and environmental costs in the price of goods so that markets can achieve efficient use of energy and resources. The U.S. government has typically relied on regulatory actions to achieve this aim, but may now be moving more in the direction of market-based incentives. Moreover, many key legislators are persuaded that the model of extended producer responsibility, popular in Europe, offers a mechanism for encouraging producers to heed environmental costs in the design of their products. Legislation requiring producers to “take back” their products at the end of the life cycle make them ultimately responsible for its final disposition.

The new administration appears to be committed to a course of emphasizing environmental goals within a framework that permits rational trade-offs with the need for economic growth and development. Increased government R&D spending, much of it in cooperation with private industry, provides a foundation for the search for technical solutions to environmental problems. The Clean Car program is a major example of how this approach may affect the automotive industry.

EPA appears to lack the anti-business rhetoric that many feared, and is shifting to more of a pollution prevention approach rather than a pollution clean-up response. In addition, the director now has a credible staff in place. In spite of the fears of many, NAFTA is unlikely to have major adverse environmental consequences for the United States, and may actually improve Mexico’s capability to enforce its fairly stringent regulatory regime.

The give and take of politics will certainly determine exactly how the balance of environmental and economic considerations will be achieved in numerous specific decisions, from take back through recycled content legislation to the permit processes governing both new and old facilities.

IV. The fourth report (Postconsumer Disposition of the Automobile, UMTRI Report #90-40-4, by T. David Gillespie, Daniel Kaplan, and Michael S. Flynn) reviews the issues and challenges that postconsumer automotive plastics pose over the different disposal stages. The United States currently has an economically viable vehicle recycling industry, composed of dismantlers, shredders, and resin producers. Increased automotive plastics content and requirements for its recycling present enormous challenges to this industry. Developing



appropriate markets for recycled stock is a critical challenge. Mandated, rather than market-led, recycling could threaten the very existence of this recycling industry and doom recycling efforts.

Shrinking landfill capacity and rising prices threaten the recycling industry, which must dispose of superfluous material. Increased nonrecyclable plastic content threatens profits, as it often replaces material that can be sold and increases the volume of residual material for landfilling. For plastics to be profitable, the labor costs associated with recovery must be lowered and/or the price of recovered materials rise. Development of automated sorting, chemical and physical technologies for reduction, and pyrolysis all offer some hope, but the public opinion environment and automotive industry demands may force the pace of recycling beyond the infrastructure's capacity.

There are steps the industry can take to facilitate higher recycling rates for automotive plastics. First, plastic components and parts can be designed for easy disassembly and dismantling. Second, plastics can be clearly and consistently labeled, to avoid contamination in the recycle stock. Third, designers can try to limit the numbers and types of incompatible plastics in the vehicle and within any part or component. Fourth, further development of incineration and energy recycling could well support resource conservation, and ultimately higher reuse of nonplastic automotive materials. Fifth, techniques for recycling commingled plastics merit support.

V. The fifth paper (Material Selection Processes in the Automotive Industry, UMTRI Report #90-40-5), by David J. Andrea and Wesley R. Brown) discusses the factors and issues in vehicle manufacturers' material selection decisions. Material selection in the automobile industry is an artful balance between market, societal, and corporate demands, and is made during a complex and lengthy product development process.

Actual selection of a particular material for a specific application is primarily driven by the trade-off between the material's cost (purchase price and processing costs) and its performance attributes (such as strength and durability, surface finish properties, and flexibility.) This paper describes some thirty criteria used in material selection today. How critical any one attribute is depends upon the desired performance objective. The interrelationships among objectives, such as fuel economy, recyclability, and economics, are sufficiently tight that the materials engineer must always simultaneously balance different needs, and try to optimize decisions at the level of the entire system.

The vehicle manufacturers' materials engineer and component-release engineer play the pivotal role in screening, developing, validating, and promoting new materials, although initial consideration of possible material changes may be sparked by numerous players. These selection decisions are made within a material selection process that will continue to evolve. This evolution will largely reflect changes in the vehicle and component development processes to make them more responsive—in terms of accuracy, time, and cost—to market and regulatory demands. The balancing of market, societal, and corporate demands will continue to determine specific automotive material usage in the future.

VI. The sixth paper (Automotive Plastics Chain: Some Issues and Challenges, UMTRI Report #90-40-6), by Michael S. Flynn and Brett C. Smith) is a report of the OSAT survey of the automotive plastics industry (vehicle manufacturers, molders, and resin producers). This survey collected the industry's views on recycling, often contrasted with more general automotive industry views reflected in our Delphi series. This report covers four general topics: recycling and disposition challenges; regulatory challenges and responses; recycling in material selection decisions; and the future of automotive plastics.

The industry in general views a variety of economic, technical, and infrastructural recycling concerns as more important in the case of plastics than of metals. The automotive plastics industry, while perhaps viewing these concerns somewhat differently, sees a complex set of recycling challenges, varying over both the automotive plastics production chain and the stages of recycling/disposition. The manufacturers see these challenges as more severe than do molders or resin producers, and the industry generally views market development and disassembly as more critical stages. The automotive plastics industry generally favors more emphasis on open-loop recycling and the development of the disassembly infrastructure, while evidencing little support for disposal in landfills.

Government CAFE regulations are important drivers for automotive plastics use. However, government is also moderately committed to recycling. The various levels of government are somewhat likely to establish differing regulations to encourage recycling, but are less likely to impose outright bans on any current plastics/composites. Among the range of governmental incentives for recycling, tax incentives are generally seen as useful, but more restrictive and limited actions are seen as not particularly useful. The automakers are unlikely to restrict the total amount of plastics in the vehicle, although they will probably limit the use of unrecyclable plastics and restrict the number of types of plastics in the vehicle. They are also likely to pass through any recycling requirements to their suppliers, the molders and resin producers.

The recyclability of automotive plastics is not yet a major factor in automotive materials-selection decisions, ranking far below the traditional factors. Recyclability is viewed as, at most, of moderate importance to the customer and the industry. Moreover, there are concerns about the cost of recycling automotive plastics, and very real apprehension that there is little market for them, once recycled. These considerations are likely to drive up the cost of plastics, should they be recycled, and thus further discourage their use.

Our results present a somewhat mixed picture as to the future role of automotive plastics in the North American industry, although in general a promising one. There are clear drivers for their use, including their advantages for design flexibility, and these are likely to be buttressed by more stringent fuel-economy regulations in the future. However, there are concerns about their ultimate disposition when the vehicle is retired. These concerns reflect a different environmental priority, one that the automotive industry does not yet view as a customer demand, nor as a "heavyweight" materials-selection factor.

Our survey suggests that the automotive plastics industry and its vehicle producing customers are aware of and concerned about the environmental challenges that lie ahead. Moreover, they are seeking solutions to these challenges that are environmentally sound and responsive to the demands of vehicle purchasers and users. To be sure, their views are often influenced by their own position in the plastics value chain, and they reveal some tendency to prefer solutions that impose responsibility on other stages in that chain. However, they reject solutions that might relieve their own burden, but are environmentally problematic, such as landfilling.

These papers suggest that the automotive industry's adoption of plastics and composites is moving forward. The pace of adoption is responsible, and the industry treats the environmental effects of its material decisions neither lightly, nor as someone else's problem. However, that pace is cautious, reflecting many uncertainties. These include concerns that the industry may be disproportionately blamed by the public for problems in recycling disposed materials, and apprehensions that the industry may be disproportionately targeted by government to resolve such problems. Since plastics and composites confer a wide variety of benefits, including environmental advantages, the industry may be erring on the side of too much, rather than too little, caution.

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### INTRODUCTION

As government responds to increasing public concern about the environment, many industries find themselves facing new regulations governing the disposal of their waste. The automotive industry can point with some pride to the fact that 75 percent of the car is recycled, mainly through the reuse of steel and other metals. But the remaining 25 percent, of which plastics comprise about 34 percent (by weight), goes to landfills.<sup>1</sup> Of this non-recycled component, plastics are regarded as having the highest potential for reuse, and research is currently underway to develop efficient recycling technologies.

While automotive plastics are not a very significant proportion of the nation's solid waste, they are easily identified with the manufacturers, unlike household waste. They therefore represent an easy target for concerned consumers, environmental groups, and government regulators, all seeking some combination of resource preservation, reduced solid waste, and increased recycling as elements of a resource conservation strategy.

Many of us assume that technology can provide fairly rapid and efficient solutions to our environmental problems, even if major technical breakthroughs may be necessary. To be sure, technology and technical developments are important and in some instances critical, but technology is typically only one of the necessary ingredients to resolving these conservation challenges. That may be especially true of the dilemmas posed by the reuse of automotive plastics. In fact, a variety of business circumstances and fundamental economic conditions must also be present for a material to become "green."

This paper provides an overview of the major economic issues and challenges facing the reuse of automotive plastics. There are numerous types of automotive plastics, and the exact nature and severity of the challenges to their reuse are often substantially different. However, most of these materials face these business and economic challenges to some extent. While systematically distinguishing these challenges across different

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<sup>1</sup> *Automotive Industries*, September 1992, 46.

plastics exceeds our resources, we are persuaded that the general material presented here has some bearing on the reuse of virtually all automotive plastics.

## AUTOMOTIVE STEEL: A RECYCLING SUCCESS STORY

Automotive steel, which is recycled without government subsidy or direct incentives, has become a recycling success story through a combination of circumstances, technical developments, and natural advantages of the material. Most automotive steel is now recycled, much of into high-value uses and reuses, virtually eliminating the visual pollution associated with scrapped automobiles in the 1960s. How this massive change came about may be instructive for identifying the critical challenges and barriers to the successful reuse of automotive plastics.

Steel has two attributes important to material reuse. First, steel is essentially uniform and is easily separated from other materials through the use of magnets. This means that once a car's tires and removable parts have been discarded or recovered for reuse, the car can be machine-shredded and yield a pile of usable steel scrap quickly, without requiring labor costs for hand-removal and separation of components.

Second, steel retains its structural integrity even after several cycles of reuse. A quantity of steel recovered from the hood of a scrapped car can be reused in a variety of new products, without compromising the quality of the new component. In fact, steel scrap has a "stew value," making it useful to the production of new steel; the scrap acts a coolant, controlling the temperature of the steel mixture.<sup>2</sup> Recycled steel makes up 20 to 30 percent of new batches in integrated mills, and, while much of this scrap is relatively clean and uncontaminated "plant scrap," somewhat over 10 percent of it has postconsumer origins, including automobiles.<sup>3</sup>

Technical developments played an important part in the expanded recycling of automotive steel. While some infrastructure for the recycling of steel has existed for a long time, it was these relatively recent innovations that hastened the widespread recovery and reuse of automotive steel. The major technical developments were the creation of shredder and electric furnace technologies. Shredders are large machines that

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<sup>2</sup> "Recycling State-of-the-Art for Scrapped Automobiles: Summary Report," American Iron and Steel Institute, 5.

<sup>3</sup> Personnel communication, AISI.

reduce the automobile hulk to smaller pieces that can then be easily—and economically—separated into their constituent materials.

Electric furnaces permit the economic processing of steel scrap in quantities small enough to support smaller scale facilities called minimills that compete directly with the larger, traditional “integrated” mills, which create steel from ore. With a technology-intensive production process and a median size of 500,000 tons per year, the minimills are able to locate themselves near both supplies of scrap and customer markets.<sup>4</sup> Integrated mills saw pieces of their market network disappearing, as the minimills set up shop in steel-hungry areas, and used postconsumer steel scrap to meet customer needs at lower prices.

The increasing strength of the minimills at the expense of the integrated mills was evident as early as 1984, when the 10 “Big Steel” companies looked back on a decade characterized by an 8 percent reduction in output, a 45 percent reduction in labor force, and annual losses as high as \$3.2 billion. Meanwhile, the minimills had expanded their market share from single digits to about 17 percent. Minimills began by serving the low margins of the industry, using local scrap materials to serve local markets for low-value-added steel, such as the construction industry. Rapid technological advances have enabled minimills to serve more exacting customers, reaching new parts of the market. Their advantage came from a combination of different approaches to labor-management relations (including avoidance of labor unions and profit sharing), their small size, their ability to use local scrap to serve local markets, thereby reducing transportation costs, and the inherently simpler production process involved in using scrap, rather than ore, to make finished products.

Integrated mills follow some version of a seven-step process in making finished products. They mine ore, remove impurities, crush limestone and char coal to make coke, use the coke to make pig iron, refine the pig iron, make ingots, and finally roll the ingots into sheet steel. Minimills, on the other hand, simply purchase scrap, melt it in an electric furnace, process the liquid in a continuous casting machine (a technology developed by the minimills in the 1960s), and chop it into pieces to be rolled into sheets. As table 1 illustrates, the early advantage of minimills arose from greater efficiency in virtually every category of expense.<sup>5</sup>

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<sup>4</sup> *Phoenix Quarterly* (spring 1986): 2.

<sup>5</sup> “Steel Minimills,” *Scientific American*, May 1984, 33.

**Table 1 Basic Economics of Minimills versus Integrated Mills**

Cost Dimensions	Mill Type	
	Integrated	Minimill
Investment required per metric ton of annual capacity (1978)	\$956 - 1,500	\$154 - 320
Annual capacity required to achieve economies of scale (1984)	3 - 10 million m.t.	50-300,000 m.t.
Employment cost per metric ton (1984)	\$195 - 295	\$75 - 100
Energy required per net ton, in B.t.u.'s	16.08 million	5.32 million

*Source: Scientific American*

Lower investment and raw materials costs, in particular, have enabled the minimills to put capital into the development of new technologies, in turn feeding their growth by opening up new markets.<sup>6</sup> Add to these advantages the fact that scrap costs about \$100 less than ore per metric ton of output, and the growth of the minimills appears to have been inevitable, given a reliable supply of scrap. That is where automotive shredders entered the equation. The growth of minimills was concomitant with an advance in shredding techniques that efficiently separated the steel from scrapped cars. These developments together created a market-driven steel recycling infrastructure for the automotive industry.<sup>7</sup> The infrastructure consists of independent private scrapping, shredding, and milling facilities that increasingly are serving the same markets as the “virgin” material.

A key challenge facing the automotive plastics industry is the identification of the barriers to scrap reuse and the technical and business developments that would remove those barriers, permitting plastics to become another automotive recycling success story.

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<sup>6</sup> Ibid., 34

<sup>7</sup> From telephone conversation with Daryl Martin, Auto/Steel Partnership. Also, see “Waste and the Environment,” *The Economist*, May 29, 1993, 9.

## THE STAGES OF AUTOMOBILE DISPOSITION

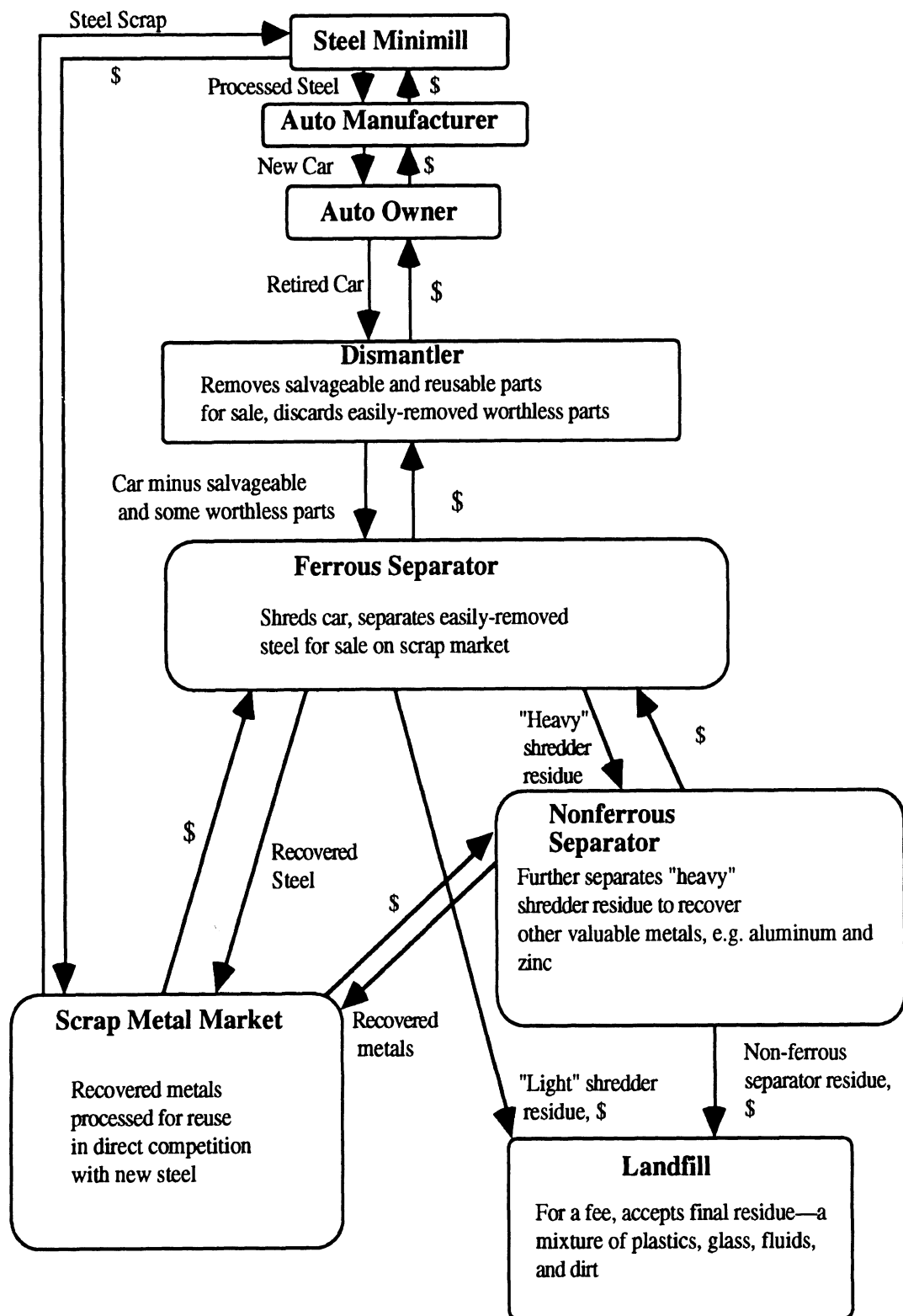
Figure 1 outlines the general process by which automotive materials are handled after the car is scrapped. Steel and other materials are removed by a succession of private entities, and plastic finally ends up in landfills, ground together into “fluff” with glass, fluids, and dirt ; this final residue is the only part of the car that has negative value.<sup>8</sup>

Most cars contain twenty or more types of plastic. In order to be reused, these must be hand-removed and separated, which introduces significant labor costs, especially where the plastics are bonded together and contaminated with adhesives and laminations. While certain types of plastic can retain their properties after being used and processed, other types cannot, and must be put to different uses. These types are shredded together in the current disposal process. Even if separation were easier, the recovered materials could not be reused until an infrastructure for processing the plastic is in place. And even if the infrastructure were in place, successful recycling would still depend on the development of end markets for products made from recycled materials. Serving end markets is generally difficult for plastic recyclers, since it is hard to predict the quality and amount of scrap that will be available at any time. This series of issues makes up the cycle of factors that play into any recycling program; failures are generally caused by obstructions blocking one or more stages in the cycle.

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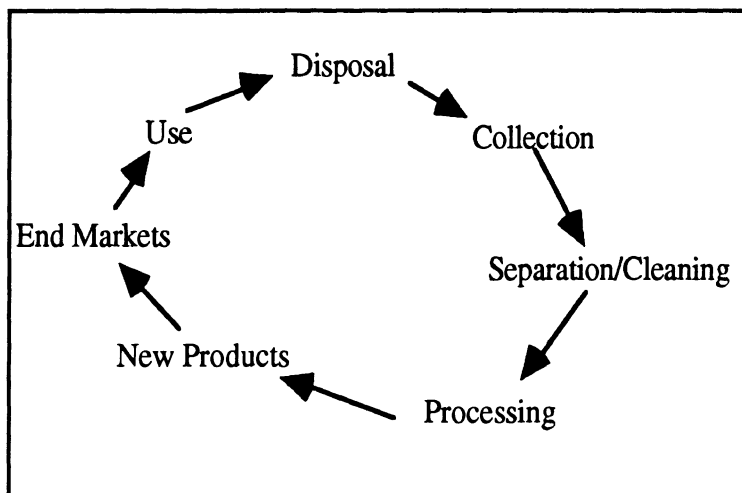
<sup>8</sup> "Cost Simulation of the Automobile Recycling Infrastructure: The Impact of Plastics Recovery," *Automobile Life Cycle Tools and Recycling Technology*, Society of Automotive Engineers SP-966, 45.





**Figure 1 The Automotive Recycling Process**

Figure 2 illustrates an idealized "closed loop" recycling program, whereby products return to their original use, and are recovered and reused virtually forever. More likely for most materials is an "open loop" recycling sequence, whereby postconsumer materials are recovered and put to an alternate use, often one that requires a lower level of purity and performance. In these cases, the cycle is actually a spiral, returning to progressively lower end uses until the material must finally be incinerated or landfilled. The important aspect of the diagram is that it illustrates how a blockage in any stage of the cycle can upset the flow, just as blood clots upset the circulation in a living organism. The system will not function until each stage is technically and economically in line with the others. Recycling efforts that have neglected or ignored obstacles affecting any of these stages have failed, no matter how thoroughly they may have addressed particular obstacles in specific stages.



**Figure 2 The Recycling Cycle**

For example, many of the programs designed to meet public pressure for recycling have started the system up with collection, mandating that residents recycle their newspapers, or plastic bottles. Often the collection stage of the cycle was successfully implemented, but an obstruction remained—the lack of sufficient end markets to absorb the supply. One mandatory recycling program in New Jersey boosted collection of old newspapers, only to find that the lack of end markets to meet the new supply drove the price of newsprint from \$20 to \$0 virtually overnight.<sup>9</sup>

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<sup>9</sup> "Recycling Becomes a Big Business," *Fortune*, August 13, 1990, 81.

## CRITICAL OBSTACLES FOR AUTOMOTIVE PLASTICS

In the case of automotive plastic recycling, two large blockages exist. The first is in the separation/cleaning stage, where the labor cost required to remove and separate the plastics from automobiles is excessive.<sup>10</sup> In the recycling of consumer plastics from curbside collection programs, automated sorting systems have shown great promise in reducing labor costs for separation; these systems mechanically separate discarded plastic bottles and scraps according to their material. The type of separation that operates on whole containers is called macrolevel separation.<sup>11</sup>

For automotive plastic, macrolevel separation requires an extra step, since the plastic components are attached to the inside or outside of a car hulk. Currently, macro-level separation is the technique stressed in most pilot programs, and the excessive labor costs required to pry plastic pieces from car hulks has been a major difficulty in making these programs work. The commonly suggested strategy for addressing this problem is "designing for disassembly," an idea that is not new, and is not confined to the auto industry.<sup>12</sup> Designing for disassembly (DFD) means creating cars that will, when scrapped, be easy to take apart because the pieces are attached with reversible fasteners, and because gaps have been provided to ease the use of crowbars (these qualities also make repairs easier during a product's lifetime). A BMW demonstration model, the Z1, can be disassembled in 20 minutes, with no special equipment.<sup>13</sup>

DFD would help to reduce the cost of disassembly, but the removed parts would still have a variety of different types of plastic in them and would be contaminated by paint and adhesives, unless designers can also "design for usability." That means making plastic parts that come off uncontaminated and contain only types of plastic that can be processed and used together—ideally, just one type per component. The director of BMW's disassembly plant in Landshut, Bavaria, says that cars do not need the 20 or more types of plastic they typically use: "Five would be much better, and should be possible."<sup>14</sup>

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<sup>10</sup> See Michael S. Flynn and Brett C. Smith, "Automotive Plastics Chain: Some Issues and Challenges," (University of Michigan Transportation Research Institute report no. 93-40-6, 1993), 7-11, for more detailed industry views of these challenges.

<sup>11</sup> "Automatic Microsorting for Mixed Plastics," *BioCycle*, April, 1992, 19.

<sup>12</sup> See, for example, "Built to last--until it's time to take it apart," *Business Week*, September 17, 1990, 102. The article discusses the adoption of design for disassembly by Whirlpool, Digital Electronics Corporation, Electrolux, 3M, BMW, and General Electric.

<sup>13</sup> *Ibid.*, 102.

<sup>14</sup> *Ibid.*

Research conducted by Porsche indicates that the best techniques for pursuing DFD involve combinations of easily dismantled parts manufactured from a single recyclable resin; for example, a bumper system for which the sheath, core, and beam are all made from polypropylene could be easily removed and recycled. Porsche concluded that DFD, while it can conflict with designing for optimal use, is realistic and reasonable when confined to specific, readily accessible assemblies.<sup>15</sup>

A study carried out by Helmut Hock, of Angus Environmental Ltd., and M. Allen Maten, Jr., of the American Plastics Council, demonstrated the importance of design in facilitating the efficient recovery of automotive plastics for recycling.<sup>16</sup> In evaluating the operations of five Michigan dismantlers asked to remove and separate plastic parts from scrapped automobiles, the researchers found that many parts were incorrectly labeled, or not labeled at all. Design characteristics such as modular components, inconsistency of polymer use by part type, and complexity of fasteners tended to make recovery difficult. Various types of contamination also "tend to be related to the design of the components rather than the types of material used."<sup>17</sup> These challenges affected the difficulty of dismantling each component differently. Total time required for removal and decontamination ranged from 25 seconds for a battery clip to 405 seconds for front and rear fascia. Some components, including headrests and grille panels, were considered impossible to remove or to decontaminate.<sup>18</sup>

Several overseas automakers have begun implementing DFD in their production. Ninety percent of the plastic parts used in Peugeot's new cars are made from only seven different resins; Opel's Calibra features thermoplastic single-resin bumpers; Reko and DSM are working on designs for dashboards that make them easy to remove; Mazda is seeking to reinforce its polypropylene and polyethylene with liquid crystal polymers instead of glass or carbon, making possible repeated reuse without degradation; Renault uses polypropylene from recycled battery cases in new car parts. Nissan has responded to German recycling initiatives by recovering bumpers from Nissan vehicles scrapped in Germany; the bumpers are sent to Hoechst for conversion to recycled resin and reused in Nissan air ducts, bumpers, and foot rests.<sup>19</sup>

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<sup>15</sup> A. Weber, *Kunststoffe German Plastics* 80, 4 (1990): 13.

<sup>16</sup> "A Preliminary Study of the Recovery and Recycling of Automotive Plastics," *Automotive Life Cycle Tools and Recycling Technology*, Society of Automotive Engineers SP-966, 59.

<sup>17</sup> *Ibid.*, 62.

<sup>18</sup> *Ibid.*, 67.

<sup>19</sup> *Plastics Engineering*, March 1993, 88.

U.S. auto companies have not implemented DFD to this extent, but are currently exploring its potential applications. Auto industry suppliers have endorsed a uniform plastics marking system (prepared by the Society of Automotive Engineers) intended to facilitate the recycling of plastic components.<sup>20</sup>

It is conceivable, though not likely, that new technology could remove the separation obstacle and bypass the disassembly problem, by enabling the postshredder fluff to be separated inexpensively into usable materials. This would require advances in either micro- or molecular-level separation. Microlevel separation operates in shredded, mixed materials, such as fluff, sorting them according to their chemical properties. Froth flotation, for example, involves the submersion of mixed fragments in liquid, followed by the release of bubbles from underneath the mixture. The bubbles adhere to different materials according their chemical makeup, and roughly uniform fragments can then be skimmed from the top. Other microtechniques include repolymerization (a chemical treatment that yields resins similar to virgin), color sorting, chemical/molecular sorting (which sorts plastics according to the temperature at which they dissolve in xylene), and density separation.<sup>21</sup>

Molecular separation even bypasses the problem of separating materials. These techniques break down materials to the atomic level, creating usable substances from the basic building blocks of matter. The complexity required to achieve this degree of near-alchemy makes this approach more remote and probably the least viable.

The second obstacle in the cycle arises in the end market stage, and is most severe when the collection and separation are carried out on a macrolevel, as is currently the case. Even with an infrastructure for collecting and separating automotive plastic, recyclers cannot rely on a consistent flow of particular types of plastic scrap. The scrap will vary, primarily according to the types of plastic used in cars seven to ten years earlier, and the contamination will vary as well. Furthermore, if the infrastructure is not uniform or governed by uniform standards, the supply of scrap could vary according to the different processing techniques used.

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<sup>20</sup> Ibid.

<sup>21</sup> Ibid., note 9, 19.

Recyclers have found that unexpected shifts in scrap content, like the change from plastic to aluminum bottle caps by soft drink companies, can destroy their ability to produce usable products from scrap. Companies that have labeled their products to contain some percentage of recycled content have had great difficulty getting dependable supplies of scrap, even from the most widely collected types of plastic.<sup>22</sup> In some cases, they have had to settle for what is available, rather than what they need. "Lots of off-spec HDPE is sold to companies that claim they're using postconsumer recycle," says Mary Mahoney, marketing director for a Pennsylvania scrap broker. "I know, because I sell it."<sup>23</sup>

Addressing this problem will require that the market for plastic scrap be rationalized and organized in such a way that scrap users know what the material is, how much is available, and what is a fair price. To the extent that automotive plastics can join the ranks of other recycled plastics as a commodity, the solution for them may come with the entry of plastic scrap into the commodity exchange market. David Dougherty, of Washington State's Clean Washington Center, is currently negotiating with the Chicago Board of Trade, which was created in 1850 to help American farmers deal with problems similar to those faced by scrap dealers today.

Ideally, entry into the CBOT would standardize material specifications for plastic scrap, lead to more competitive pricing, and allow for real price discovery for various materials.<sup>24</sup> To be sure, plastic scrap may face some particular challenges not shared by agricultural products, including persistent price fluctuation, greater demand-side instability, and a lack of inherent value. Assuming that companies continue to pursue greater recycling capacity, these problems should not prove insurmountable. Until such market rationalization takes place, however, recyclers must deal with the problem of unstable and unpredictable supply.

A short-term approach to this problem, for individual recyclers, is to develop contracts with suppliers and end users that allocate the risks from changing supply and demand among these three parties. More efficient contracts have made a difference for recycling programs that have suffered from sinking prices. As in the New Jersey

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<sup>22</sup> Rubbermaid and Procter and Gamble are two such companies: see "Recycling in Fits and Starts: Harsh Economic Realities Force Consolidation," *Chemical Week*, October 28, 1992, 46.

<sup>23</sup> "Recycling Update: High Noon in High-Density PE," *Plastics Technology*, July 1993, 96.

<sup>24</sup> "Two States of Market Development," *Waste Age*, December 1992, 83.

example given above, neglecting to consider the importance of the size of end markets relative to supply can doom a recycling program. Even if the market is initially big enough to absorb the collected material at a price that is acceptable to the municipality, a sudden shrinkage in the end market can still drive prices down and turn the collection operation into an unreasonable burden. Contracts with provisions such as escape or adjustment clauses to dampen the impact of falling prices can reduce the recycler's risk to a reasonable level. The proof lies in the success of the WTE Corporation, which had \$15 million in revenues during 1989. WTE makes its money by buying and managing failed recycling operations, after rewriting their contracts.<sup>25</sup> This represents a short-term solution because it does not fundamentally change the aggregate market behavior of scrap suppliers and users.

Another approach to the problem of unstable scrap supply is the technology-based, market-driven method of recycling being developed by GE's Polymerland division. Polymerland, Inc., the distribution and servicing company GE formed in 1990 to help create a national plastics recycling network, has made some progress in recycling postconsumer and other types of plastics scrap, including automotive plastic.<sup>26</sup> According to R. Kaskel, Polymerland "...set out to solve the landfill issue by buying all of the engineered thermoplastics that we could, and to attack the purchased scrap with Ph.D. chemistry to create world problem-solving polymers. We failed!" All of their initial products, Mr. Kaskel says, either were affordable but lacked demand, or were in demand but not affordable. In other words, they never managed to clear the obstructions from all stages in the cycle simultaneously.

Their response was to change their strategy to "market-driven recycling," whereby the needs of the market are assessed first, and the combinations of scrap plastics capable of meeting this need are developed second. In pursuing this strategy, Polymerland scientists found a way around the chronic problem of unstable and unpredictable scrap supply. They identify particular physical properties for which demand exists, then develop a "feedstock matrix," which specifies several combinations of scrap plastic feedstock that can be used to achieve the desired characteristics. Because they specify more than one combination of feedstocks, they can change the recipe when necessary, increasing the odds that they can use whatever the scrap market has to offer at the time.

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<sup>25</sup> Ibid., note 8, 81.

<sup>26</sup> Ibid., note 10, 102.

This strategy of "market-pulling," rather than "market-pushing" has enabled Polymerland to serve the automotive aftermarket's demand for affordable materials that meet engineering thermoplastic requirements. They are also supplying recycled plastics to the printer ribbon, plumbing, and materials handling markets, and are planning entry into the construction and extrusion markets. Mr. Kaskel says that the strategy has been successful enough that recycling of engineering thermoplastics is profitable for Polymerland.<sup>27</sup>

Their experience's broader implications for recycling efforts depend on their success in increasing the postconsumer portion of the feedstock they use for recycling, currently 20 percent of the total. Factory-floor and chemical plant scrap, which make up the rest, has been recycled for a long time; postconsumer scrap is the linchpin of the solid-waste problem in automotive as well as general recycling. Polymerland currently recycles postconsumer plastics from pizza trays, water bottles, and car bumpers, as well as other consumer discards.

Polymerland's example is instructive for companies or governments becoming involved in recycling. GE's scientists avoided the common mistakes by recognizing that two necessary stages in the cycle—the end market and collection/processing stages—were beyond their control. They took that lack of control as their starting point, and applied their expertise to the remaining stages in such a way as to make it irrelevant. Other entities may be able to address their role in recycling similarly, by trying to find a way to clear the obstructions from the recycling cycle through their particular expertise. This strategy has also been used by governments that have complemented their recycling efforts with market development programs designed to stimulate demand for recovered plastics.

These programs take advantage of the government's special position as a grant issuer, overseer of monopolies, and focal point for efforts to make industry serve public objectives, in order to clear some of the obstructions from the end-markets component of the cycle. New York State's Office of Recycling Market Development, for example, funds research and development, cooperative marketing ventures, feasibility studies, and low-interest loans to businesses developing new uses for postconsumer plastics. New York also negotiates with newspapers and telephone book publishers, asking them to

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<sup>27</sup> "Demand Driven Recycling of Engineered Thermoplastics," Society of Plastics Engineers/Plastics Engineering ANTEC 1992 Conference Proceedings, 2369-73.



make their products with recycled content.<sup>28</sup> Other governments have made similar efforts in market development, and almost 30 states have developed semi-independent entities to purchase and/or market postconsumer plastics.<sup>29</sup> About the same number singled out plastics as the most difficult recycled material to market, in a survey by *Waste Age Magazine*, indicating that market development may be more important for plastics than for other recovered materials. A survey of municipal governments by the Municipal Waste Management Association found that the biggest barrier to successful recycling programs is the availability of markets.<sup>30</sup>

The termination of a recycling partnership, the Plastics Recycling Alliance (PRA), between DuPont and Waste Management, Inc. shows that a recycling program that focuses on one stage of the recycling cycle and fails to put the company's particular expertise to work clearing the remaining obstacles may encounter difficulty. PRA succeeded in recycling HDPE, which was sold to DuPont, but DuPont was never heavily involved in marketing this type of resin. They finally sold their interest in PRA to a company with more appropriate experience, Illinois Tool Works, which makes products using the types of plastics handled by PRA.<sup>31</sup>

While innovative as a recycling technique, Polymerland's "market-driven" approach is fundamental to most businesses—they see a need, and they arrange to satisfy it. The fact that this approach has been the exception, rather than the rule, in the recycling arena illustrates the unusual nature of recycling as an industry.

Most recycling programs did not begin with the recognition of a demand for a new product, but rather with the recognition of the supply of solid waste. The public came to view solid waste as an unwanted oversupply, and created a demand for its reduction, ideally through its reuse in existing products. Cities and towns found their citizens asking for collection programs targeting recyclable waste; satisfying this demand meant starting up curbside collection programs. However, such programs simply created two streams of

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<sup>28</sup> "Two States of Market Development," *Waste Age*, December 1992, 83.

<sup>29</sup> "1993 State Recycling Budget Survey," *Waste Age*, April 1993, 46.

<sup>30</sup> "Availability of Markets Remains Biggest Barrier to Recycling," *Recycling Times*, Feb. 9, 1993, 1. Our survey of the automotive plastics industry agrees with this assessment: Michael S. Flynn and Brett C. Smith, "Automotive Plastics Chain: Some Issues and Challenges," (University of Michigan Transportation Research Institute report no. 93-40-6, 1993), 9.

<sup>31</sup> "DuPont to Sell Its Interest in Plastics Recycling Alliance," *Recycling Times*, June 30, 1992, 1.

waste: reusable and disposable. It did not guarantee actual reuse. For local governments, it guaranteed expenses, but in and of itself promised no revenues.

Private companies and governments alike have found that demand for recycled content or for recycling programs does not always translate directly into "demand," in the economic sense. A recent survey by the Council on Plastics and Packaging in the Environment found that 66 percent of respondents were willing to pay \$8 per month to recycle 25 percent of their waste, but past studies have indicated that only about half of those who say they are willing to pay more will actually do so.<sup>32</sup> Another study found that consumers are less likely to pay more for recycled products than they say they are, particularly during a recession.<sup>33</sup> Similarly, politicians and interest groups may suggest that the public demands more recycled content in their cars, but auto companies cannot be sure that they will buy the greener cars when they are available.<sup>34</sup>

Another GE recycling project more exclusively devoted to automotive plastics was General Electric's partnership with Luria Brothers, of Cleveland, Ohio. This project demonstrates the difficulty of creating a profitable automotive plastics recycling program when the two major obstacles in the cycle—disassembly labor costs and unstable supply for serving the end market—are not addressed. Luria Brothers, a scrap metal dealer, was to recover body panels, bumper fascias, and other exterior parts made from GE PC/polyester blends from scrapped cars. These parts would be removed from cars prior to shredding, and sent to GE to be converted into a polymer with ABS-type applications, building material applications, and other nonengineering end uses. The recovered material was expected to have high thermomechanical properties relative to ABS, enabling GE to sell it at a premium above ABS.

The partnership was disbanded when it became clear that the procedure was not feasible. GE explained that they did not receive an adequate supply of uncontaminated plastic parts on a constant and reproducible basis, and they were paying too much for laborers to hand-separate plastic components from scrapped cars.<sup>35</sup>

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<sup>32</sup> "Americans are More Aware that Recycling Costs Money," *Recycling Times*, September 22, 1992, 1.

<sup>33</sup> *C&EN*, June 1, 1992, 14.

<sup>34</sup> Flynn and Smith, *op. cit.*, 19-23, finds that recycling is at best a minor consideration in automotive material selection, largely because of its perceived low value to customers.

<sup>35</sup> R.H. Burnett and G.A. Baum, "Engineering Thermoplastics," *Plastics Recycling: Products and Processes*, R.G. Ehrig, ed. (New York: Hanser Publishers, 1992), 157.

In summary, the minimum requirement for the success of a recycling program is that all of the stages in the cycle be cleared of obstructions that prevent the flow of recovered plastics from the consumer back to the consumer. The starting point can be the demand/end market stage, as in the example of Polymerland's market-driven approach, or the supply/collection stage. In Kingsport, Tennessee, for example, curbside collection began when Eastman Chemical joined with Waste Management, Inc. to create a recycling facility.<sup>36</sup> Beginning with the demand stage has the potential to prevent difficulties that arise because of the unpredictable nature of scrap supply, but is limited in the amount of postconsumer scrap it can reuse.

For the rest of the collected postconsumer scrap, markets must be developed. This process is aided by public buying patterns favoring products with recycled content, and by government procurement regulations, both of which are limited in their effect. Our survey suggests that the industry believes that some form of federal requirements on minimum recycled content are more likely than not, but think this is at best a moderately useful way to incentivize recycling.<sup>37</sup> But finding or creating markets for plastic scrap will continue to be extremely difficult as long as scrap users cannot be reasonably sure of the amount and quality of scrap they will be able to buy, and at what prices.

#### ELEMENTS OF RECYCLED MATERIALS COSTS

Assuming that these hurdles are overcome, and new plastic will be usable for the same purposes as recycled plastic, some economic feasibility issues remain. The criterion for a successful recycling effort under these conditions is determined by the following equation:

$$\begin{aligned} &\text{Dismantling Cost /lb.} && \leq && \text{Total Cost/lb. New Plastic} \\ &+ \text{Transportation Cost/lb.} \\ &+ \text{Recovery Cost/lb.} \end{aligned}$$

If this equation does not hold, potential users of recycled plastics will use cheaper new plastic, and no market will exist for the recycled material. If it does hold, and is sufficiently stable, a market could take shape, particularly if consumer concern for

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<sup>36</sup> "The Environment: Industry's Talent for Solutions," *Industry Week*, January 4, 1993, 25.

<sup>37</sup> Flynn and Smith, *op. cit.*, 15, 18.

recycling actually translated into an economic value attached to the purchase of products with recycled content.

The need for stability presents another difficulty: since the recycled product would be in direct competition with new plastic, the profitability of each will depend on their relative production costs. This fact does not present a risk for the potential users of recycled plastic; if we assume that they can easily substitute new for recycled plastic, they must benefit from the existence of a second supplier. But for the recycled and new plastics industries, changes in relative cost could be devastating. Because their buyers can immediately substitute new for recycled plastic, or vice-versa, the supplier with even a small cost advantage could underprice the other for as long as the advantage lasted.

Even without a cost advantage, the industry with stronger financial backing could sell at a loss for long enough to capture the market. In fact, existing small-scale recyclers of HDPE are complaining that large resinmakers are doing just that—creating a glut of recycled HDPE by selling at a loss, to steal recycling market share from them.<sup>38</sup> This risk may prevent independent processing facilities from entering the scrap plastic industry, assuming no government protection is provided.<sup>39</sup>

By the same logic outlined above, the larger steel mills could (theoretically) gain an advantage over the "minimills." But the integrated mills tend to keep their prices stable, leading some to accuse them of insufficient competitiveness. Another view is that the larger, established producers have stable prices because of their existing, long-term agreements with customers. According to this theory, consumers pay more to buy from the integrated producers because they offer reliability and guaranteed delivery, reducing the risks associated with uncertain supply.<sup>40</sup>

The issue of relative price changes when the alternative to landfill is a type of reuse other than closed-loop recycling. If automotive plastics are processed to be put to completely different uses, they must compete with other materials. One type of processing, for example, can turn automotive plastics into home heating oil, putting the recovered material in competition with existing sources of heating oil. Processed

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<sup>38</sup> "Recycling Update: High Noon in High-Density PE," *Plastics Technology*, July 1993, 96.

<sup>39</sup> According to Bruce Vernyi, the demand for recycled plastic is extremely responsive to price, and the lack of an infrastructure guaranteeing supply causes price instability.

<sup>40</sup> C. J. Erceg, P.R. Israilevich, R. H. Schnorbus, "Competitive pricing behavior in the U. S. steel industry," *Economic Perspectives*.

automotive plastic may become increasingly attractive as an alternative to these sources as they become more scarce. Even without an increase in the price of competing materials, processed plastic may be preferred for public policy reasons where existing sources create a dependence on foreign suppliers.

Achieving affordability for recycled plastic will require attention to each of the components of the equation on page 16: dismantling, transportation, and recovery.

Dismantling Lower dismantling costs will require designing for disassembly, labeling plastic components, simplifying the plastic content of cars, and developing a system for quickly removing and separating these components. However, even an immediate, concerted effort on the part of auto companies to pursue all of these avenues will not bring about a rapid drop in dismantling costs, since the existing stock of cars will be scrapped before most of the newer cars. A long-term plastic recovery program should anticipate several years of higher costs, lasting until the redesigned cars begin to be scrapped.

Because the automakers will have to devote some expense to working out these designs, and because they may see any constraints on design as a threat to their competitiveness, these efforts are not likely to occur without either government intervention or a credible threat of intervention. Facing strict German auto recycling laws, BMW has begun altering the design of its instrument panels, making some panels entirely of one material. This type of design innovation reduces the processing required for recycling, since the instrument panel usually includes different types of plastic in its hard outer skin, foam filling, and support framework.

Transportation The most important factor in lowering transportation costs is the creation of a network of dismantling and processing facilities easily accessible to scrap yards and to the final markets. This could be achieved through the direct involvement of government in building or providing incentives for processing facilities, a government mandate that dealers or automakers must process automotive plastics, or the introduction of plastic processing technology that can make plastic recovery profitable for existing dismantlers.

Making use of the existing infrastructure of shredder facilities has been suggested, but would be very difficult unless plastic scrap processing becomes profitable. The Institute of Scrap Recycling Industries has published an official position on solid waste

recycling, asking the government to avoid recycling programs that would cut into their business by diverting their inputs. They recommend that the government develop markets before beginning collection programs and avoid creating recycling programs that duplicate the activities of scrap processors.<sup>41</sup> Because of their small scale, these businesses may not be able to deal with government-mandated recycling, but they will be likely to take advantage of advancements that allow them to make profits from materials that they currently send to landfills. Automotive industry actions with regard to materials choices and recycling are particularly important for shredders, since car hulks represent about 75 percent of the material they process.<sup>42</sup>

Another suggestion is that dealerships' service departments become responsible for collecting recyclable plastic parts. This proposal carries some intuitive appeal, since dealers currently collect used motor oil, and should be adept at removing and reusing parts from cars they are accustomed to servicing. It does complicate the disposal process, however, and added transportation costs for the car hulk could cut into the profits of scrap processors. Perhaps the manufacturers' delivery vehicles for parts and vehicles could be utilized for transporting hulks and parts for recycling, since they typically return empty. Nevertheless, since forcing an unprofitable recycling process on any private entities is very problematic, and since scrap processors already receive and process car hulks, making recycling profitable for them is probably the most efficient method for promoting recycling.

Whatever network emerges, economies of scale should form as more plastic is separated and recovered, so that the portion of the cost per pound of recycled plastics attributable to transportation may steadily decline. Materials handlers working with widely collected consumer plastics have recently begun to realize significantly lower transportation costs by making more bulk shipments, using rail transport, and locating reprocessing facilities as close as possible to collection centers.<sup>43</sup>

Recovery Once the plastic components are collected and separated into appropriate types, they can be processed according to their intended end use. At this point, the costs will vary with the type of plastic and method of recovery.

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<sup>41</sup> "The Scrap Processing Industry and the New Recycling Movement," *Phoenix Quarterly* (winter 1987), 2.

<sup>42</sup> *Plastics Engineering*, March 1993, 88.

<sup>43</sup> "Materials handling improvements reduce final cost of reclaimed resin," *Modern Plastics*, May 1993, 77.

The above analysis outlines the conditions necessary for a profitable recovery and reuse process. Net gains or losses from the process over time will depend on the level of labor costs, fuel costs, and technology used in each of the above stages. Recycling in general has suffered from the fast growth in labor costs for dismantling recycled materials relative to the cost of virgin materials.<sup>44</sup> Plastics recycling in particular has been hampered by the low cost of oil, a primary input into the production of virgin resins. Some who have studied the issue believe that no foreseeable improvements in recycling technology or in design for disassembly will be able to overcome the excessive cost of recycled resin relative to virgin, as long as cheap oil is available. It has been estimated that oil prices would have to double in order to make recycling a good long-term investment (that is, a 10 percent annual yield), even though the initial investment for a virgin-resin production facility is five to ten times as great as for a recycling facility.<sup>45</sup>

One recycler has already discovered that oil prices can directly affect the profitability of recycling. The Plastics Recycling Alliance, which was created by DuPont, experienced a boost in prices and sales during 1991, when tensions were high in the Persian Gulf; later, when the situation stabilized, recycled resin prices fell rapidly.

Nevertheless, some pilot projects have shown that the recycling of certain types of automotive plastic can be profitable for an independent dismantler, but only on the assumption that the dismantler receives tipping fees comparable to those charged by more expensive landfills.<sup>46</sup> Realistic prospects for profitability of automotive plastics recycling are hampered by the same two obstacles that have made profitable recycling of other postconsumer plastics difficult: the excessive labor costs required for separation, and the difficulty of meeting end-market demands with unpredictable supplies of scrap.

## NONRECYCLING OPTIONS FOR AUTOMOTIVE PLASTICS DISPOSITION

The disposition of solid waste from automobiles includes options other than recycling. These options range from the environmentally unattractive landfilling to the less unattractive energy recovery, and we now turn our attention to these possibilities.

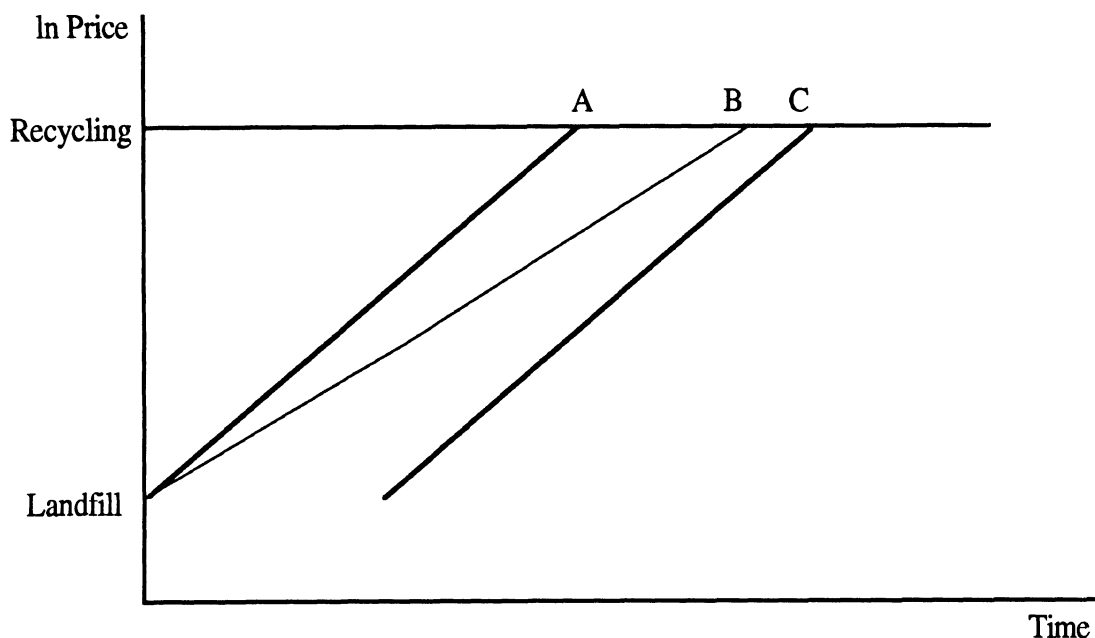
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<sup>44</sup> "Waste and the Environment," *The Economist*, May 29, 1993, 6.

<sup>45</sup> "Waging War on Waste," *Distribution*, April 1992, 39.

<sup>46</sup> "Recycling Sheet Molded Composites (SMC)," "Plastics Recycling as a Future Business Opportunity," (Plastics Institute of America Recycling VI Conference, 1991). The study estimated that a 6.4% annual return was achievable from recycling sheet molded composites (SMC) with a \$60 per ton tipping fee.

The landfill option The story does not end, however, with the determination of the profitability or unprofitability of auto plastics recycling. Even if it was profitable, auto companies may prefer the virgin resins with which they are familiar, and they may fear legal liability from using recycled plastics that may be implicated in accidents.<sup>47</sup> On the other hand, sourcing recycled plastic—even at a net loss—may prove economically attractive for automakers if all available alternatives cost more than the expected loss. Landfills charge a per-ton tipping fee low enough to make them the most economical choice for disposition of plastic and the other components of fluff. But tipping fees have been increasing rapidly, and the time when they cease to be the most affordable option may not be far off. A study of recycling programs in Washington state, for example, found that recycling is cheaper for that state than solid waste collection, even though selling postconsumer materials does not cover the cost of collection.<sup>48</sup> Nationwide, the cost of recycling programs ranges from \$35 to \$199 per ton, while landfill costs range from \$36 to \$102 per ton.<sup>49</sup>



**Figure 3 Landfill vs. Alternate Disposition Over Time**

<sup>47</sup> It is not clear how much of an issue legal liability may be; a plastics industry analyst suggested some concern on the part of auto companies, while an auto company representative felt that it was not an issue.

<sup>48</sup> "CWC Study: Recycling Costs Less but Materials Don't Cover Expenses," *Recycling Times*, June 15, 1993, 1.

<sup>49</sup> "Recycling, Source Reduction, and Opportunities for Biodegradables," *Plastics Engineering*, March 1993, 81.



Figure 3 above illustrates a general principle regarding the use of a material for which alternative technologies exist.

The natural log of price is plotted on the vertical axis, against time, on the horizontal axis.<sup>50</sup> Line A represents the cost of using landfills to dispose of recycled plastics; it is assumed that these costs will rise steadily, since available land, regulations, and especially transportation costs will continue to put upward pressure on price. Line C portrays the effect of an innovation affecting price, such as the development of a new means of compaction that allows landfills to accept more waste, while line B indicates the effect of a higher discount rate, which would cause businesses producing plastic waste to be less concerned about landfill costs far off in the future.

The steepness of line A is an important factor in determining when landfilling becomes a less attractive alternative to recycling, at the point it crosses the top horizontal line, representing the price of recycling. Because the cost of recycling is not yet dependent upon a diminishing resource—although a potentially unstable one—the price is assumed constant over foreseeable time. To be sure, it is also possible that technological innovation could cause this line to slope downwards.

How steep line A is and will be is difficult to estimate, although there is reason to believe that its slope may become steeper. A recent five-year national study reported that landfill closings were ten times the level of new openings. Although the newer landfills tend to have larger capacity, this statistic is indicative of a rising tide of public opposition to new landfills, which could result in a scarcity of landfill space over time.<sup>51</sup> The direction of legislation affecting landfill, both domestically and internationally, is also towards more enforced scarcity.<sup>52</sup> Employees of auto companies, resin makers, and parts molders surveyed by OSAT gave very low emphasis to landfill expansion as a means of resolving automotive waste issues, probably because they recognize this trend.<sup>53</sup>

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<sup>50</sup> To be sure, since these lines are natural logs, they bend at some point, as price increases flatten out. For simplicity, we show these prices passing the price of recycling before that develops.

<sup>51</sup> "Landfill Capacity in North America," *Waste Age*, May 1992, 24. This article also finds that public opposition to new landfills is the most significant barrier to their construction, and that the number of states reporting a decline in landfill capacity rose over the period studied.

<sup>52</sup> *Ibid.*, note 30, 9.

<sup>53</sup> Michael S. Flynn and Brett Smith, "Automotive Plastics Chain: Some Issues and Challenges," (University of Michigan Transportation Research Institute report no. 93-40-6, 1993), 8.

The movement towards greater landfill regulation is especially significant considering that a recent survey by the National Solid Wastes Management Association (NSWMA) indicates "a distinct relationship" between the average tipping fee and the level of environmental protection provided by landfills within a region.<sup>54</sup> Although an actual scarcity of available land for landfill is not imminent, reduction of the total number of landfills means that individual governments will be sending their waste to more and more distant landfills, and that increased transportation costs will join with cost increases due to environmental regulations and community resistance, driving total landfills costs upward. Because landfill costs are increasingly reflective of transportation costs, they will move more closely with the price of oil.

If the assumptions underlying figure 3 are tenable, it is only a matter of time before an alternative to landfill will emerge as the optimal choice for plastic users. The determination of the optimal choice depends on a variety of cost and price factors, some of which are external to the automotive and plastics industry. If, for example, the price of home heating oil were to increase, the processing of automotive plastic for this use could become more attractive. In this case, the graph could be reworked to show an upward-sloping line representing the cost of heating oil, and a horizontal line representing the cost of processing plastic for this use *minus* the (averted) landfill cost. Information on the slope of the landfill cost line, and the likelihood of shifts in that line and in the alternative technology line, would make possible a forecast of the year in which this takes place.

According to the NSWMA survey, tipping fees in the various regions of the country (Northeast, Mid-Atlantic, South, Midwest, West Central, South Central, West) ranged from \$11.06 in the West Central region to \$64.76 in the Northeast in 1990. The unweighted average regional fee was \$28.00. The range of price increases also varied widely between 1988 and 1990, with the smallest increases in the South (3 percent) and the highest in the West (32 percent). The unweighted average annual increase across regions over this two-year period was 9 percent. A preliminary study of automotive plastics recycling by pyrolysis (the depolymerization of plastics into petrochemicals in an oxygen free environment) estimated revenue and expenses. Results suggest that pyrolysis could be profitable at a combined pyrolysis fee and averted landfill cost of \$72.60 per ton of material.<sup>55</sup>

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<sup>54</sup> "NSWMA Releases Expanded Tipping Fee Survey," *Waste Age*, December 1991, 26.

<sup>55</sup> "Cost Simulation of the Automobile Recycling Infrastructure: The Impact of Plastics Recovery," *Automobile Life Cycle Tools and Recycling Technology*, Society of Automotive Engineers SP-966, 45.

It is difficult to estimate just what levels tipping fees will reach and how they will vary across the nation, because land prices, transportation costs, and regulations will all play a role in determining that price. However, if we apply our 9 percent increase estimate to the 1990 average price, tipping fees could rise to this level, making pyrolysis profitable without requiring a fee, by the year 2001.<sup>56</sup> Even a closed-loop recycling effort could (despite greater expense) become the preferred option over time, since virgin plastic is made from petroleum, a nonrenewable resource.

Incineration In the short term, the first alternative to landfill that could become attractive by this rationale might be incineration, which is generally cheaper than recycling. While incineration makes possible the recapture of the energy content of plastics, it presents some of the same problems as landfill. Incinerators may emit toxic substances, they are difficult to locate close to residential areas, and they leave behind ash residue that must be landfilled or reused. They do have the potential of harnessing energy, but this is not worthwhile unless the user is very near the facility. Given these considerations and the momentum and direction of popular perception regarding waste disposal, public opposition could become as much of an obstacle to incineration as it is currently to landfills. Nevertheless, depending on the technology available for cleaning furnace exhaust and the quality of ash residue, incineration may be the preferred option.

If the incineration were to be carried out on the site of the shredding operation, and the energy was used to power the shredder facility, it could become feasible fairly soon. Shredders are already located in industrial areas, so community resistance should not be prohibitive, and the problem of requiring a nearby user is solved by putting the energy to work directly on site. The financial feasibility of such an operation, assuming no government involvement, reflects the cost of building and running the incinerator compared to the combined savings on energy and landfill fees (the latter should be reduced by about 70 percent). The feasibility of fluff incineration is therefore dependent on the price of electricity, as well as the price of landfill and the available technology. The shredder may even be able to sell the ash residue, which is more uniform and predictable than fluff, for low-end uses such as construction aggregate.

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<sup>56</sup> If a "national" price developed at the lowest regional level (\$11.06), then tipping fees will reach this level by 2012; tipping fees in the Northeast may have passed this level sometime in 1992.

Turning again to the SAE study, the estimated combination of averted landfill cost and incinerator fee required to make incineration profitable (assuming 70 percent weight reduction of landfill) is \$61.25 per ton. Using the average tipping fee projection outlined above, this could be the rate of landfill tipping fees by 1999.

Scrap processors built at least 23 incinerators to handle shredder residue by the end of 1973, but all have since been closed. According to a study by the Argonne National Laboratory, they were shut down because community resistance and the cost of gas scrubbers and high temperatures to deal with chlorine, sulfur, and PCBs made incineration more expensive than landfill.<sup>57</sup> These conclusions suggest that a cross-industry strategy may be necessary to promote incineration, similar to the strategies already mentioned in regard to recycling.

Designing for incineration, for example, could be applied to automobiles as well as appliances and other products that eventually meet at the shredder; it would imply designs that exclude hazardous materials where possible, and which allow for the easy removal of remaining hazardous materials prior to shredding. This technique could be used in combination with design for disassembly, allowing for a reduction in plastics solid waste of more than 80 percent. Finally, the solid waste could be reduced to zero by developing end markets for the ash. BASF is investigating the feasibility of incineration of shredder fluff and other materials with a planned power station designed to use these materials.<sup>58</sup>

Whatever the economics of incineration, however, it is chronically unpopular compared with recycling. This statement from a recent book by the Environmental Action Coalition is illustrative of the attitudes of environmentalists toward incineration:

Ultimately, responsible policy decisions must be based on the realization that nothing in the municipal solid-waste stream is "entirely safe" to burn, nor is there any one material solely responsible for the emission of toxic substances.<sup>59</sup>

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<sup>57</sup> "Automobile Shredder Residue: Treatment Options," *Hazardous Waste and Hazardous Materials*, Summer 1991.

<sup>58</sup> *Plastics Engineering*, March 1993, 88.

<sup>59</sup> Nancy Wolf and Ellen Feldman, *Plastics: America's Packaging Dilemma*, (Washington, DC: Island Press, 1991), 63.

Environmentalists are typically joined in the fight against incinerators by anyone living close enough to a proposed site to worry about the fumes, making a large-scale shift to incineration doubly unlikely. Just as people seem to support energy conservation in their roles as voters, but not as automobile consumers, any support for incinerators or landfills appears to stop when they might be located in one's backyard.

Government regulations as well as technology and resource diminution can also be decisive factors, by causing shifts in the landfill price line (taxes/penalties) or the cost-of-alternatives line (subsidies, research and development).

## PUBLIC POLICY INTERVENTION

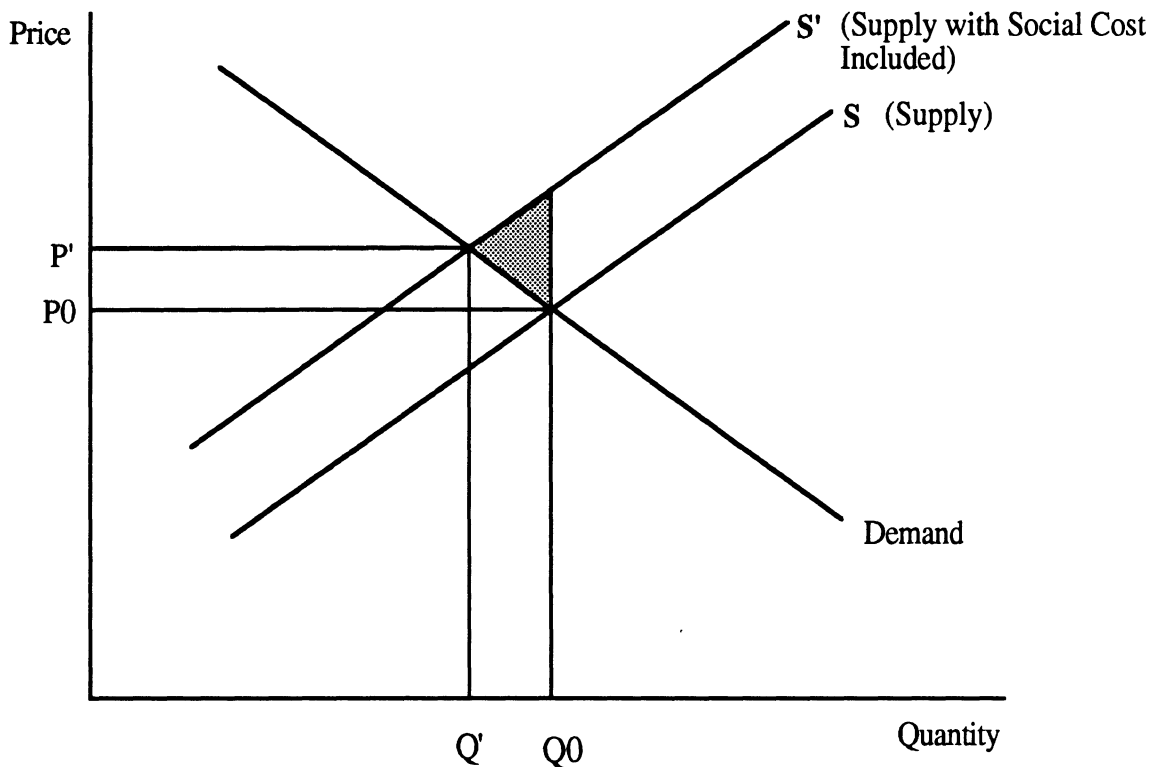
To this point, we have discussed the prospect of various government actions with regard to automotive plastics reuse, without explicit justification. There are persuasive reasons for the government to become involved in promoting the reuse of automotive plastics.

First, the use of plastic in automobiles is partially the result of government policy in the first place. Government CAFE standards create pressure on automakers to raise the average fuel economy of their cars; automakers respond by substituting plastic components for metal, which makes the cars lighter and therefore more fuel efficient. To the extent that the recycling of automotive plastics increases the viability of the material, it contributes indirectly to the public objective of increased fuel efficiency. This objective is in turn directly linked to the objective of reducing the nation's dependence on foreign oil. The same objective is served even more effectively if the recycling effort is a closed-loop application, since virgin plastic is made from petroleum. Even for open-loop applications, however, preserving the viability of plastics helps the government to achieve public objectives because of the relative energy efficiency of plastic, which requires far less energy than steel in the initial production phase.

Second, the recycling of automotive plastics serves to reduce the auto industry's contribution to another public policy challenge: the disposal of nonreusable wastes in landfills. Any waste diverted from landfills helps to extend landfill lives, and reduces the possibility of a waste disposal crisis. Finally, the avoidance of landfill use serves the general public by reducing the impact of an "externality." An externality is

a benefit or a cost of a market transaction that is neither paid for nor received by those making the transaction, and is therefore not incorporated into the market demand or supply.<sup>60</sup>

Figure 4 provides a graphic representation of an externality.



**Figure 4 Externalities**

The downward-sloping demand curve indicates the various prices buyers of a product would pay, dependent upon the quantity available in the market. The upward-sloping supply curve S indicates that various amounts that producers will supply, given the price they can get for the product. Given these supply and demand curves, an unrestricted market will settle on a price of P0 and a quantity Q0.

In some cases, however, there are parties affected by a transaction who are not reflected in the supply and demand curves that determine price and quantity. In the case of landfills, these may be people who live near the landfill, and experience falling property values, odors, or chemical pollutants. If the costs to them of expanding the landfill were included in the determination of price, the supply curve would rise to S',

<sup>60</sup> Edward M. Gramlich, *A Guide to Benefit-Cost Analysis*, 2nd ed., (NJ: Prentice-Hall, 1990), 18.

signifying that the social cost of any quantity of landfill exceeds the price paid by the users. The shaded area between the two supply curves represents the excess burden to these people of the market-determined quantity of landfill. At the socially optimal price, P', users create no externality by transacting with landfill owners.<sup>61</sup>

Incorporating the concept of externality into the inequality presented earlier yields the following:

$$\begin{array}{l} \text{Dismantling Cost /lb.} \\ + \text{Transportation Cost/lb.} \\ + \text{Recovery Cost/lb.} \end{array} \leq \begin{array}{l} \text{Total Cost/lb. New Plastic} \\ + \text{Marginal Social Cost/lb.} \\ \text{of Landfilling Plastic} \end{array}$$

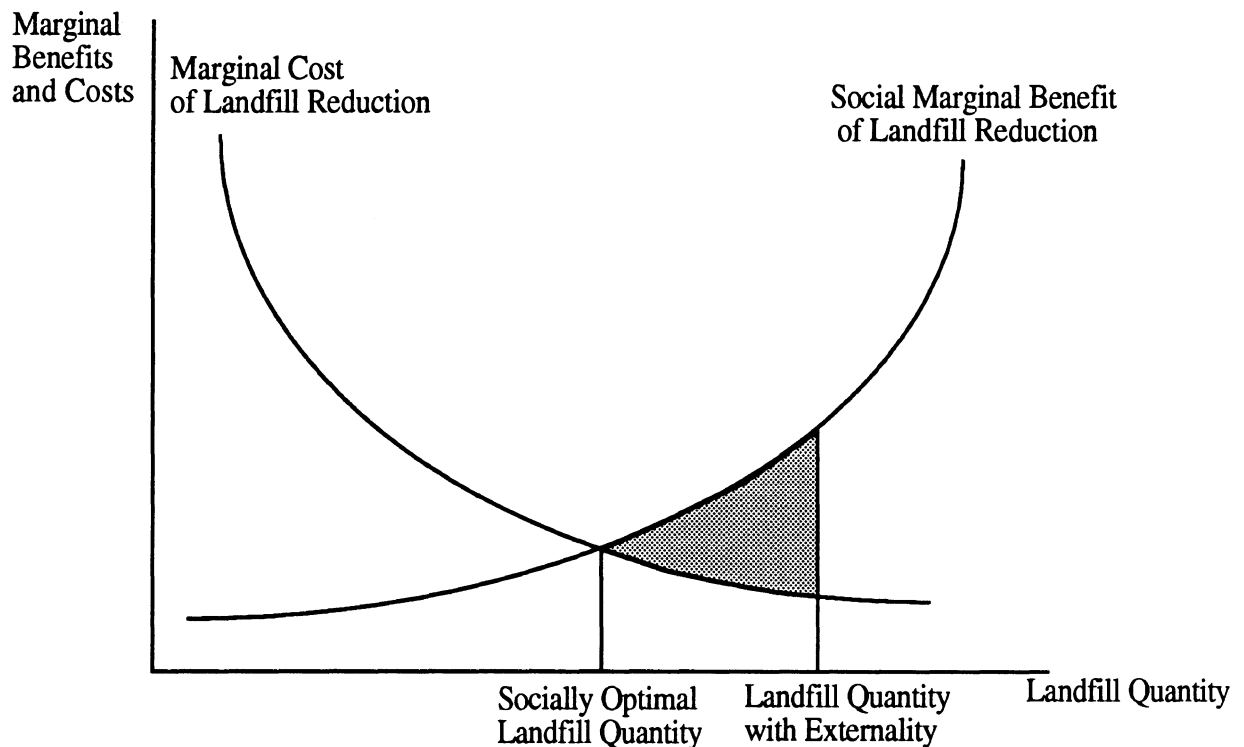
This revised equation incorporates the externality by allowing the cost of recycled plastic (the left-hand side of the equation) to rise higher before exceeding the right-hand side, now that social cost has been added as a cost of failure to recycle.

Figure 5 depicts another representation of the socially optimal quantity of landfill. This graph depicts an externality as a condition in which the marginal social benefit of reducing the amount of landfill exceeds the marginal cost of reduction. Because the benefits accrue to people who are not involved in the transactions determining the amount of landfill created, the movement to the socially optimal level cannot be expected to result without the intervention of government. The public sector must be involved in order that the industry, which bears most of the cost of landfill reduction, consider marginal social benefits relevant to its decisions. With the externality, the social burden resulting is represented by the shaded area. At the socially optimal level, further reduction in landfill would still carry some social benefit, but not enough to justify the marginal cost to the industry.

Disputes over the necessity of landfill restrictions may focus on the question of where society currently finds itself along the horizontal axis. This approach generally calls for an approach to solid waste that falls somewhere between that of industry, which tends to resist being held responsible for externalities, and that of environmental groups, who often protest the idea that there is a nonzero optimal quantity of landfill.

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<sup>61</sup> Some economists argue that all these externalities are reflected in the prices of efficient markets, in the long run. Thus the externalities of landfills decrease the price of the land in its neighborhood, and, while that may hurt some current landholders, in the long run, it is reflected in the discount. How efficient given markets are is always a debatable proposition.



**Figure 5 Socially Optimal Quantity of Landfill**

Of course this discussion no longer describes a market without government interference. Unless the marginal social cost is somehow made relevant to the parties to the transaction, the externality will go uncorrected. Government policy could attempt to address the externality by taxing the landfill owners or users, or by restricting the amount of landfill that can be used, pushing landfill use towards the social optimum level. Such actions would affect all industries using the landfill to dispose of waste, causing them to pay higher prices, and in turn to charge consumers higher prices for the products creating the waste. If the correction of the externality works efficiently, consumers would see the higher prices as a fair tradeoff for the smaller landfills. This or similar logic has been compelling to governments at all levels, as they address solid waste issues. In Quebec and Germany, automobile shredder residue has been declared hazardous waste, and banned from landfills.<sup>62</sup>

<sup>62</sup> This type of analysis seems to underlie many of the actions of the German government discussed in Suzanne M. Cole, "Recycling the Automobile: A Legislative and Regulatory Preview," (University of Michigan Transportation Research Institute report no. 93-40-3, 1993).

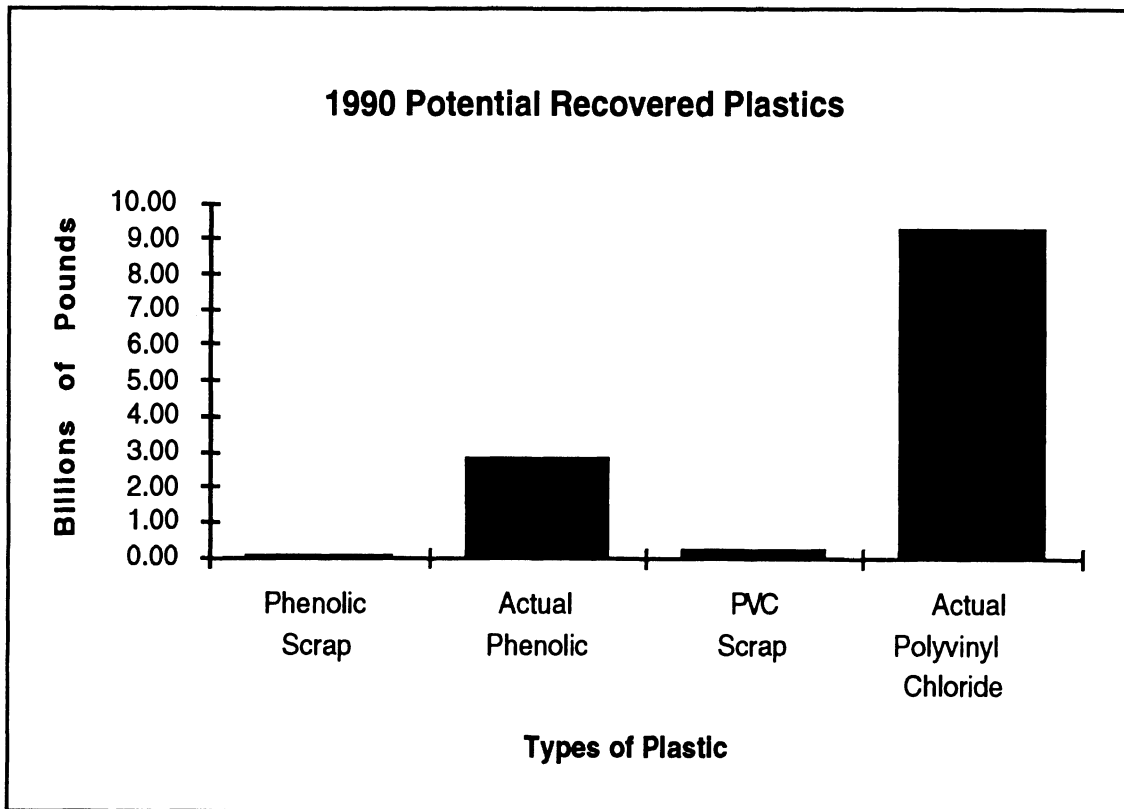


Other consequences of automotive plastic recycling must be considered public concerns because of their impact on the macroeconomy. If all or most of the plastics in cars were to be recycled and sold in competition with new plastic, makers of new plastic industry could lose market share. The suppliers of inputs to new plastic would also face permanently lower demand. These concerns also apply to the introduction of open loop recycling: suppliers of materials that will compete with processed plastic will face lower demand as more automotive plastic is processed. Depending on the structure of demand for plastic, the introduction of recycled plastic in competition with new plastic could lower the price and affect profitability.

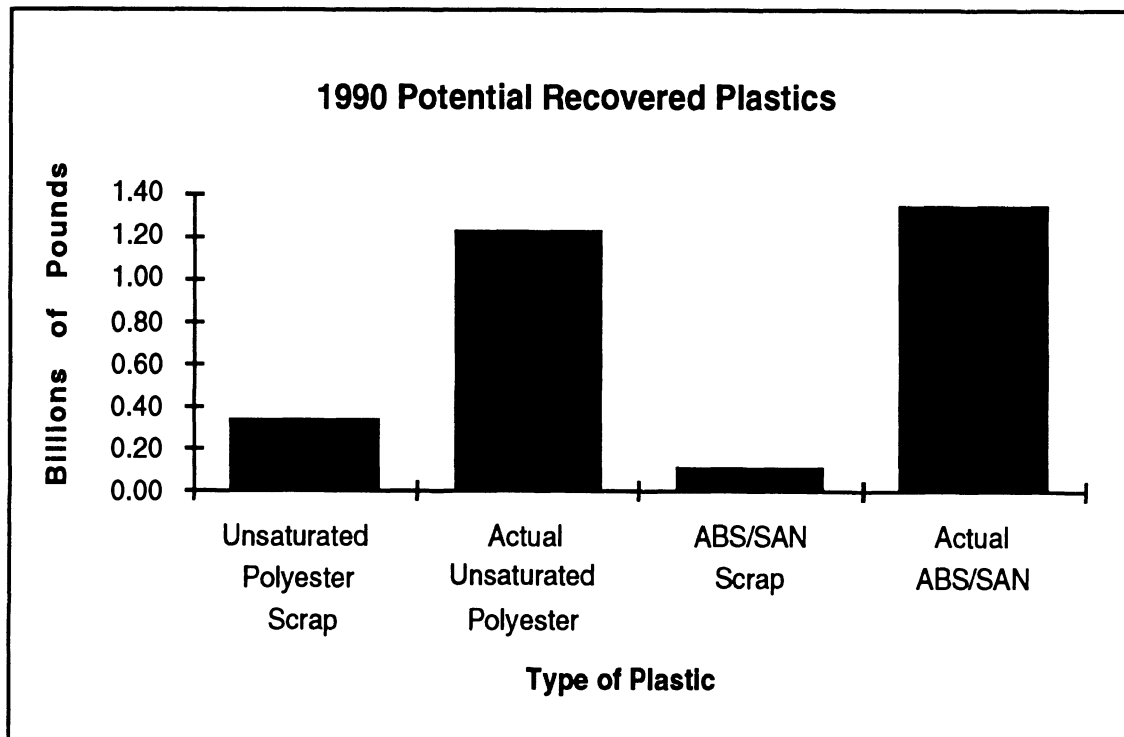
Figures 6-8 demonstrate that, for certain types of plastic, 100 percent recovery and processing of scrapped cars would yield amounts large enough, relative to the total market, to have an impact (assuming that the technology existed to allow scrap to compete with its virgin counterpart). These diagrams are based on estimates of the total amount of plastic, of each type, that could be recovered from all of the cars and trucks actually scrapped in 1990 (see appendix I). The estimation takes into consideration the number of cars from each model year scrapped in 1990, and the approximate amount of plastic used in vehicles during each model year. The total amount of plastic available from cars scrapped in 1990 is graphed alongside the total sales of the same type of plastic in 1990, to suggest the potential significance of automotive scrap in the market.

The comparison indicates that phenolic, polypropylene, and PVC from vehicles are a relatively small amount relative to the total market (1.06 percent, 3.50 percent, and 2.58 percent, respectively), while recovered polyurethane, nylon, and particularly unsaturated polyester are potentially very large proportions of the total markets (10.38 percent, 10.52 percent, and 26.89 percent). Especially with regard to these latter materials, some care will have to be taken in implementing a large-scale recycling effort, to prevent an oversupply that could damage the viability of recyclers and resin producers alike.

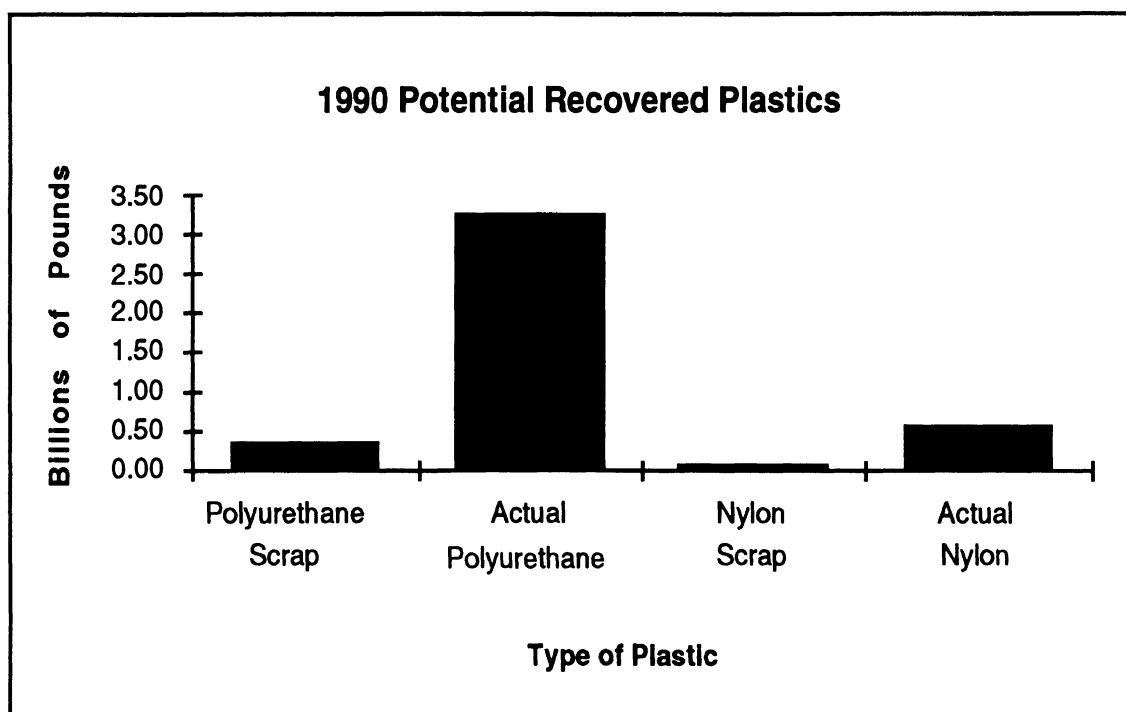
Any impact of public policy regarding automotive plastic recycling on either the auto industry or the plastics industry could affect the competitiveness of these products internationally. If mandated collection causes an oversupply of recovered plastics, and they are sold abroad, they could disrupt recycling efforts in other countries. Germany's



**Figure 6 1990 Potentially Recoverable Scrap vs. 1990 Market, Phenolic and PVC**



**Figure 7 1990 Potentially Recoverable Scrap vs. 1990 Market, Unsaturated Polyester and ABS/SAN**



**Figure 8 1990 Potentially Recoverable Scrap vs. 1990 Market, Polyurethane and Nylon**

mandated collection has caused some friction by making scrap available to recyclers in England and France for free, or even paying them to accept it. Scrap processors in these countries have accused Germany of neglecting to develop markets for the scrap they have begun to collect.<sup>63</sup>

All of these consequences must be considered part of the potential cost or benefit of recycling. Whatever conclusions are drawn from such an analysis may be moot, however, insofar as the momentum behind recycling efforts is the public perception of recycling as a “merit good.” That is, some people seem to support recycling efforts even if the recovered materials are worth less than the cost of recovery; they see recycling as valuable for its own sake, and may be willing to pay for it. By the same token, recycling may add value to a product in the eyes of consumers. Companies that can label their product as partially recycled may find themselves able to charge a higher price, or at least to gain market share, which could compensate them for the extra money spent on including postconsumer materials in their products.<sup>64</sup> The success of BMW’s 3-Series

<sup>63</sup> “German Efforts Seen as a Threat,” *Chemical Week*, February 17, 1993, 20.

<sup>64</sup> Rubbermaid, for example, has found that “higher post-consumer plastic content ... is becoming a very competitive issue,” driving the price of high-quality post-consumer resins above that of virgin resins (“Major Technology and Market Factors which Drive Successful Plastics Recycling Programs,” Society of Plastics Engineers/Plastics Engineering ANTEC Conference Proceedings, 1992, 2354).

car in Britain, where its 82 percent recycled content was heavily advertised, suggests that car buyers may exercise a preference for "green" cars.<sup>65</sup> In its U.S. dismantling facilities, BMW has tried to add to the market attractiveness of recycling by offering owners a \$500 "incentive" credit for their scrapped BMW's. The incentive can be put toward the purchase of a new or used BMW. The company's U.S. pilot recycling operations have been set up in Orlando, Florida, Bronx, New York, and Santa Fe Springs, California.<sup>66</sup>

Some of the public education programs carried out by advocacy groups can also help to create demand for recycled products among consumers; a few even focus on this goal explicitly, by stressing the idea that consumers should "vote with their pocketbooks." The Council on Economic Priorities (CEP), a New York public interest research group, has been involved for many years in promoting the concept that consumers should make the environmental and ethical behavior of companies a factor in their everyday purchasing decisions. CEP has published five editions of a pocket-sized handbook called *Shopping for a Better World*, which includes ratings of major companies making goods available in the supermarket; they have sold almost a million copies. The book is designed to make the application of corporate citizenship concerns as easy as possible. Shoppers looking for cereal, for instance, simply stop at the cereal aisle, pull out the handbook, and choose the variety made by the company with the best rating on issues of importance to them. According to CEP researcher Ben Hollister, surveys indicate that 97 percent of readers considered the environment their top priority.<sup>67</sup> The 1994 edition will be the first to include ratings of automotive companies, with information on the U.S. operations of the Big Three, Honda, Toyota, and Nissan.

## CONSEQUENCES FOR THE INDUSTRY

Because the issues surrounding waste disposal touch on a variety of public policy concerns, the auto industry may need to consider the public's perspective almost as important as their own estimates of the costs and returns of recycling. Ignoring public concerns could create a problem that comes back to haunt automakers later. In the United States and abroad, companies have been required to pay for the cleanup of waste from their products, even when the disposal was legal at the time. Aggressive requirements for the recycling of automotive materials, which have already been proposed by members of

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<sup>65</sup> "Recycled Roundels," *Autoweek*, January 11, 25.

<sup>66</sup> *Ward's Automotive Yearbook 1993*, Ward's Communications, 1992, 36.

<sup>67</sup> From an August 18, 1993 telephone conversation.

Congress, could be forthcoming. If they catch the industry unprepared, the market shares of individual manufacturers could be threatened by other companies producing greener cars.<sup>68</sup>

Even without legislation, automakers must consider the possibility of an increasing buyer preference for recyclable vehicles, which could also cut into market share for an unprepared company. Every year that goes by without a modification in car designs to resolve some of the waste disposal issues mentioned in this paper may be creating a future liability for manufacturers, who could find themselves saddled with increasingly more stringent requirements to deal with the waste from their products when they are scrapped. This is why pilot projects and research efforts are currently being pursued by the Big Three and foreign companies, as an investment to reduce future costs and market challenges.

If the government acts to minimize the amount of landfill created by automotive residue, they may choose from several incentive or regulation mechanisms.<sup>69</sup> They could create a refundable deposit on new automobiles, the effects of which would depend on the way the deposit amount was calculated. For example, a uniform across-the-board deposit should not cause much shifting in market shares. A tax on virgin materials could also be used to make recycling more attractive, but could be more complicated to administer. Taxing the use of landfill itself could make recycling or incineration more attractive, but may not compel a switch to an alternative method until some "threshold" cost is reached. Minimum-content requirements have also been suggested for automotive plastics, and are relatively popular with environmental groups and voters.

Among the more extreme measures proposed for the U.S. auto industry is the emulation of policies recently proposed and implemented in Germany.<sup>70</sup> Proposed legislation under consideration by the German government would levy a tax on new cars to pay for their eventual disposal. Germany's environmental minister has proposed that, by the end of 1993, car manufacturers be responsible for the final disposal of their cars; he also recommends that auto makers recycle 20 percent (by weight) of the plastics in their cars by 1996, and 50 percent by 2000. Draft legislation submitted in 1991 would

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<sup>68</sup> See S. Cole, *op. cit.*, on the likelihood of these developments.

<sup>69</sup> See Flynn and Smith, *op. cit.*, for a review of industry views on these various governmental mechanisms.

<sup>70</sup> See S. Cole, *op. cit.*, for a discussion of some of these German regulations and their attraction to U.S. legislators and regulators.

require new cars to achieve 25 percent recycled material content by weight ; it would also require auto makers to establish systems for accepting, sorting, and recycling parts from old automobiles.<sup>71</sup> While these proposals are more stringent than U.S. regulations are likely to be, U.S. automakers generally prefer this type of "standard-setting" approach to "method" regulations forcing them to use particular technologies, if some type of regulation is inevitable. They prefer to face industry-wide standards, which maintain a level playing field and allow them the latitude to develop their own techniques for meeting the standards.<sup>72</sup>

Whatever action the government considers taking to promote plastics recycling, it will have to exercise caution to avoid disrupting the balance of supply and demand in the scrap materials industry. As countless examples have demonstrated, government collection programs that are not combined with market development, or targeted to serve an existing market with excess capacity, can destroy the profitability of recycling. Where independent companies have already begun recycling scrap, excess supply can drive them out of business, and the net effect may be no more or less recycling than existed before collection was mandated. In fact, the attraction of minimum content laws, from the perspective of government, is that they go directly to the heart of the issue that so often disrupts recycling programs—the lack of end markets—by legislating them into existence.

This approach to increasing recycling by forcing markets to demand recycle is seen as artificial and disruptive by many industry representatives. In testimony before Congress, William Carroll, of Occidental Chemical Corp., pointed out:

There would be no glut of recycled materials if the consumer perceived their value and demanded them. There is no glut of Nintendos; no need to mandate consumption of light beer. But they apparently do not perceive the value of recycled materials, despite all the advertisements, public service announcements, news programs, and environmental activists.<sup>73</sup>

He also argued that mandates would not help existing recyclers, because they would cause the prices they pay for inputs to rise. Mr. Carroll's reasoning is reflected in the views of other industry representatives and analysts, but may not be convincing to

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<sup>71</sup> M.M. Nir, J. Miltz, and A. Ram, "Update on Plastics and the Environment: Progress and Trends," *Plastics Engineering*, March 1993, 77.

<sup>72</sup> Frank Field, "Materials Technology: Auto Design and the Environment," for U.S. OTA.

<sup>73</sup> "Congress Debates Problems with Plastics Markets," *Recycling Times*, April 7, 1992, 1.

government policymakers.<sup>74</sup> From their perspective, recycled materials are fundamentally different from Nintendos and light beer insofar as their consumption serves to reduce an externality, and thereby to serve a public objective. In fact, the adverse impacts on existing private recyclers caused by government-stimulated demand may not be a major concern for policymakers. A policy will be judged effective to the extent that it reduces solid waste, regardless of which private entities win or lose, except where job losses could result. Where policies might cause people to lose their jobs, policymakers are likely to weigh these adverse consequences against the expected benefits of the policy, and proceed if the benefits are expected to outweigh the costs.

Policymakers may also turn to studies such as the one carried out by the League of Women Voters in 1992, based on their survey of 423 newspaper publishers and 567 solid-waste officials. Eighty-five percent of the solid waste officials surveyed said that lack of markets was a serious or a moderate barrier to plastics recycling. The League concluded that minimum content regulations would solve this problem, and pointed to successful mandated recycling of old newspapers to support this assertion.<sup>75</sup>

OSAT carried out a similar survey of resin suppliers, molders, and manufacturers recently to determine which issues surrounding recycling of various automotive materials were considered most important.<sup>76</sup> Responses indicate a consensus that development of markets and reduction of separation labor costs are among the most important challenges facing automotive plastics recycling. Furthermore, 80 percent of the Delphi VI Technology panel predicted that state or federal regulatory action will be introduced in the coming decade to enforce the recyclability of automotive materials in the United States. Our plastics survey respondents see limits on materials that can be landfilled as likely at the state, federal, and local level; required minimum recycled content and end of product life-cycle recyclability requirements were also seen as likely objects of federal legislation.<sup>77</sup>

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<sup>74</sup> See, for example, "Do We Need a Federal Garbage Man?" by Ken Chilton, of the L.A.-based Reason Foundation. Chilton argues that market creation doesn't require public sector intervention, since the mismatch of supply and demand in potential markets is only temporary. Mandating markets, he says, creates more problems than it solves.

<sup>75</sup> "League Advises Minimum Recycled Content for Markets," *Recycling Times*, March 10, 1992, 1.

<sup>76</sup> Flynn and Smith, *op. cit.*

<sup>77</sup> *Ibid.*, 10.

Given these government actions, survey respondents expected automakers to cut down on unrecyclable plastics, use fewer types of plastic per vehicle, and pass through recycling requirements to suppliers (suppliers considered this last action slightly more probable than did manufacturers).<sup>78</sup>

Aside from direct regulations on recycling, an increase in fuel-efficiency standards under CAFE could create more pressure on automakers to devise plastics recycling technologies, by causing an increase in the plastic content of cars. According to OSAT's Delphi VI survey, a relatively modest increase in CAFE standards from 27.5 to 30 m.p.g. by 1995 would lead to a 13.5 percent increase in the plastics content of cars. Higher CAFE levels would lead to even higher plastics content.

Some innovative means for dealing with solid-waste issues also have recently been suggested and attempted. A few economists have recommended taking an example from the sulfur emission, tradable credits system. The system sets an overall ceiling on the amount of emissions permitted, and allocates to each polluter a set of credits, each of which represents the "right" to emit a certain amount of pollution. Companies that develop cleaner technologies can sell some of their pollution rights to other companies. Thus, the ability to profit from emission reduction creates an incentive for each company to develop these technologies. Since companies do not currently pay to pollute in the absence of such a system (that is, there is no air pollution tipping fee), the analogy to landfill use is not direct. A recycling credit, based on the requirement that companies include a certain proportion of recycled content in their products, would create a similar set of incentives.<sup>79</sup>

Current investment in recycling technologies could carry an extra payoff in the future should such a system be implemented, as those manufacturers who can easily exceed recycled content requirements sell their credits to others who fall short. In theory, such credits might be convertible across environmental arenas, permitting a company that exceeds minimum content requirements to apply those credits against its shortfall in reaching emission standards. Such a system of tradable environmental credits would also permit setting governmental priorities regarding the environment, as the credit "exchange

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<sup>78</sup> Ibid., 11.

<sup>79</sup> These have been suggested by several economists; see, for example: "Recycling Credits may Stimulate Sluggish Markets," *Recycling Times*, June 30, 1992, 2.



rate” among the different arenas would determine the relative incentive—and market—value of efforts to earn them.

Another novel proposal, made in a study by Frank Field, suggests that landfills be restructured as materials “mines,” carefully segregating, sealing, and labeling their contents, in the hope that they will become valuable and someday be reused.<sup>80</sup> This approach could yield future benefits, unless it dampens the incentive to develop technologies for the reuse of automotive plastic, and the segregated landfills are seen as a way to delay indefinitely more intensive reuse efforts. It does mean taking a gamble on the eventual development of a suitable technology. Landfill “mining” has been attempted with current landfills, but not on any large scale. Consequently, the feasibility and effects of this procedure are not yet clear.<sup>81</sup>

Whatever the shape of future legislation or other government action on this issue will be, the Big Three automakers hope to be ready. In recognition of the importance of the waste disposal problems associated with their product, they formed a coalition, the Vehicle Recycling Partnership, to study the issue. Mr. Sandy Labana, who had headed up Ford’s plastic recycling research, says that the automakers favor an approach to plastic recycling that will mirror the system by which automotive steel is recycled. Their reasoning, he says, is that the supplier networks providing automakers with their plastic materials and components are the appropriate organizations to make plastic resource recovery feasible—not the automakers themselves. They feel that plastics companies have the greater expertise and knowledge about the various types of plastic and recovery options for each.

The Big Three, says Mr. Labana, have informed their suppliers that they will exercise a preference for recycled plastics (of the same composition as new plastics) over virgin materials, once the price is competitive. They expect most of the work required to make recycled materials compete directly with new plastics to fall on the plastics companies themselves, although the industry intends to pursue design for disassembly and other means of facilitating recycling. Just as the steel industry currently manages the reuse of scrap steel, automakers would like to see the plastic companies oversee the reuse of automotive plastic.

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<sup>80</sup> Frank Field, “Materials Technology: Auto Design and the Environment,” for U.S. O.T.A.

<sup>81</sup> See, for example, “Landfill Mining Merits Serious Consideration,” *BioCycle*, May 1993.

For the time being, automakers and resin makers are both involved in a stream of strategic decisions with the government. The companies are aware of the political pressure building for stricter recycling requirements and/or solid waste legislation. They have some idea of what might be legislated, and would prefer to make any changes in their own way, without facing burdensome "technology forcing" regulations or minimum content legislation. This situation is nicely represented by game theory, as illustrated in figure 9 below.

		Industry	
		Reduce Waste	Not Reduce Waste
Government	Regulate	<b>1</b> 1 , -1	<b>2</b> -1 , -2
	Threaten Regulation	<b>3</b> 2 , 0.5	<b>4</b> 0 , 0

**Figure 9 Game Theoretic Representation of Industry and Government Strategic Decisions on Waste Reduction**

The first number of the pair in each cell represents the relative welfare of the government, given the corresponding government decision to regulate or simply to threaten regulation, and industry's decision whether or not to reduce the landfill waste from their product. Government derives a positive benefit from regulating successfully (cell 1) , and a negative benefit from regulating unsuccessfully (cell 2).<sup>82</sup> If government threatens regulation unsuccessfully (cell 4), it is still better off than if it regulates unsuccessfully, because it has not committed resources, and still has the option of regulation.

The biggest positive benefit, according to the suggested ordering of preferences represented here, is to threaten regulation successfully (cell 3), meaning that the industry responds to the threat with waste reduction measures adequate to forestall the need for actual regulation. This way, the government can say that it has had an effect, without imposing costly regulations that expand the bureaucracy and may become politically unpopular later. Politicians representing areas with heavy employment in this industry will also be mollified.

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<sup>82</sup> Cell identification numbers are shown in bold face.

To predict the choices made when each "player" tries to maximize utility while having no control over the other player's actions, a game theorist looks at the choice that makes the each better off *regardless of the other's actions*. Here the government is better off threatening regulation if the industry reduces its waste, and also if industry is destined not to reduce waste; therefore, government should select this option (cell 3).

Industry prefers to reduce waste in the presence of regulation, to avoid penalties and stricter regulations (cell 1 rather than cell 2). If regulation is simply threatened, industry still has a slight preference to reduce waste (cell 3 rather than cell 4), if only to prevent pressure for regulations from building and to avoid higher disposal fees in the future. Individual companies prefer to do their own research into recycling, but to put off major research expenditures until market pressures (as in the case of air bags and anti-lock brakes) or government regulations level the playing field by requiring expenses from all producers.<sup>83</sup> In other words, without knowing whether the government will regulate or continue to threaten regulation, industry prefers to reduce its waste at least enough to make it likely that the regulations are considered unnecessary.

This analysis suggests that government will typically threaten regulations rather than actually implement them, while industry is likely to reduce waste. A game in which each player's independent choices intersect in one cell is said to have a "Nash equilibrium"—in this case, cell 3. Unlike the well known prisoner's dilemma, the equilibrium here is a positive sum result. Moreover, the outcome is positive—if not necessarily optimal—for society, as waste is indeed reduced.

The point of this analysis is to explain decisional outcomes in terms of strategy between decision-making groups, and to understand their choices in terms of that strategy. An important implication of the theory is that automakers may find that a threatened regulation may be a possible alternative to regulation not merely its prelude.

To be sure, whether there is a true equilibrium solution and what the equilibrium value may be can vary with changes in the circumstances affecting each player's preferences. Government's hesitancy to enact regulations might well be reduced if it became convinced that regulations could be effective without damaging the industry.

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<sup>83</sup> Frank Field, "Materials Technology: Auto Design and the Environment," for U.S. O.T.A.

Particularly when regulations are successfully enacted in other countries, politicians may be more willing to support similar legislation. For example, Max Baucus, chairman of the Senate Environmental Committee, has already announced his intention to emulate Germany's aggressive "Green Dot" recycling program through legislation calling for manufacturers to take responsibility for the final disposal of their products.<sup>84</sup>

However, Senator Baucus and other members of Congress may be losing their enthusiasm for German-style recycling as they witness the fallout from that program in Germany and the rest of Europe. Duales System Deutschland—the entity created by producers to collect and sort materials for recycling—is reporting losses of \$180 million to \$300 million. The collection network has spent excessive amounts of money separating materials with little or no value, and neighboring countries have complained that German scrap is being dumped on their markets, threatening their own recycling efforts and companies.<sup>85</sup>

Two other players in the game, although perhaps less important for automotive plastics than for curbside-collected, household-waste plastics, are local and state governments. They are more directly burdened with solid waste problems than the federal government, and at the same time less capable of influencing industry. State and local governments have already demonstrated their willingness to pass stringent solid-waste restrictions when they perceive their landfill burden to be getting out of hand, and our plastic survey respondents think they are likely to limit landfilling of some types of materials.<sup>86</sup> Suffolk County, New York, home of the famous garbage barge, has even passed legislation banning plastic grocery bags and many plastic containers.<sup>87</sup> While nonfederal legislation affecting the design or content of automobiles is unlikely, California's clean air legislation has demonstrated that it is possible.

## LEARNING FROM THE PAST

Many of the issues discussed in this paper were also the focus of a 1972 study by the Environmental Protection Agency: "The Automobile Cycle: An Environmental and Resource Reclamation Problem." This paper estimated that the scrap metal in a car was

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<sup>84</sup> See S. Cole, 1993, op. cit.

<sup>85</sup> "Trash That Recycling Plan," *Wall Street Journal*, June 28, 1993, A16.

<sup>86</sup> See Flynn and Smith, op. cit., 15.

<sup>87</sup> This ban was recently upheld by the New York State Court of Appeals. *Plastics Engineering*, March, 1993, 76.

worth \$55.94, but was not widely recycled because of the contamination caused by copper wiring and other nonferrous materials. Its author predicted that “the accumulation of abandoned vehicles on public and private property will probably increase if no concerted action is taken.” Recommendations fell into four categories: economic incentives, regulatory action, education, and research and development; most of the incentives the report suggested involved taxes on manufacturers.

Since then, abandoned cars have ceased to be a serious problem, and the recycling of steel from car hulks has become a profitable enterprise, even as the 1993 edition of *Ward’s Automotive Yearbook* reports that the use of copper wiring in automobiles is “skyrocketing.”<sup>88</sup> In fact, the copper (as well as other nonferrous metals in automobile hulks) has become a major source of value for shredders.

The change was not brought about by government regulation, but by technological innovations in shredding and steelmaking that created a large and growing demand for ferrous scrap. Design innovations by the automakers, development of markets by the public and private sectors, and the development of technologies for serving end-market demand with postconsumer plastics can have a similar effect on automotive plastic. Ideally, a collaborative effort by government and industry can create conditions that make the recovery and reuse of automotive plastic profitable. By funding research and investing in design for disassembly, these parties can bring profitable automotive plastic recycling closer. Once this is achieved, capital investment subsidies, underwriting of loans and contracts, and removal of legislative obstacles can pave the way for entrepreneurs.

Automotive plastics can become another recycling success story. Whether that comes to pass is dependent on technical, regulatory, and market developments largely beyond the control of any one company or any one set of players. The actions of—and the coordination among—resin producers, molders, vehicle manufacturers, and the differing levels of government will determine the extent, rapidity, and efficiency of the industry’s efforts to reach that laudable goal.

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<sup>88</sup> *Ward’s Automotive Yearbook 1993*, 28.

## **APPENDIX I**

**Table 1 Plastic Contained in Cars and Trucks Scrapped in 1990**

Lbs. Plastic per Veh.	Model Year	Cars Scrapped	Lbs. Plastic	Trucks Scrapped	Lbs. Plastic	Total Plastic
221	89	16,000	3,536,000	0	0	3,536,000
220	88	121,000	26,620,000	0	0	26,620,000
217	87	91,000	19,747,000	21,000	4,557,000	24,304,000
216	86	152,000	32,832,000	34,000	7,344,000	40,176,000
210	85	257,000	53,970,000	56,000	11,760,000	65,730,000
206	84	341,000	70,246,000	69,000	14,214,000	84,460,000
204	83	341,000	69,564,000	53,000	10,812,000	80,376,000
202	82	467,000	94,334,000	61,000	12,322,000	106,656,000
200	81	650,000	130,000,000	105,000	21,000,000	151,000,000
195	80	785,000	153,075,000	97,000	18,915,000	171,990,000
100	Pre-80	5,766,000	576,600,000	1,681,000	168,100,000	744,700,000
	<b>Total</b>	<b>8,987,000</b>	<b>1,230,524,000</b>	<b>2,177,000</b>	<b>269,024,000</b>	<b>1,499,548,000</b>

1990 scrappage by model year: Ward's Automotive Yearbook 1993, p. 243

**Table 2 Automotive Scrap Plastic in 1990  
Types of Plastic in 1981 Car**

	Auto. plastics	Cars	Trucks	Total
<i>Thermoplastics:</i>				
Polyurethane Foam	0.23	278,098,424	60,799,424	338,897,848
Polypropylene	0.19	233,799,560	51,114,560	284,914,120
Polyvinyl Chloride	0.16	196,883,840	43,043,840	239,927,680
ABS/SAN	0.07	86,136,680	18,831,680	104,968,360
Nylon	0.04	49,220,960	10,760,960	59,981,920
Miscellaneous	0.07	86,136,680	18,831,680	104,968,360
<i>Thermosets:</i>				
Unsaturated	0.22	270,715,280	59,185,280	329,900,560
Polyester				
Phenolic	0.02	24,610,480	5,380,480	29,990,960
<b>Total</b>	<b>1.00</b>			

Sources: types of plastic in 1981 car: Plastics Recycling, R.J. Ehrig, ed., Hanser-New York, 1992, p. 156;

**Table 3: Automotive Scrap Plastics as a percentage of Total Sales  
Total Sales in 1990, Actual:**

	Total Sales in 1990, Actual:	90 Scrap as a % of 90 Sales:
Phenolic Scrap	29,990,960	1.06%
Polypropylene Scrap	284,914,120	3.50%
ABS/SAN Scrap	104,968,360	7.80%
Polyvinyl Chloride Scrap	239,927,680	2.58%
Unsaturated Polyester	329,900,560	26.89%
Polyurethane Scrap	338,897,848	10.38%
Nylon Scrap	59,981,920	10.52%

U.S. Plastics Sales 1990, by type: Modern Plastics, January, 1991, p. 113