REPORT OF THE

Berkeley Plastics Task Force

April 8, 1996

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INTRODUCTION

The Ecology Center convened the Berkeley Plastics Task Force in February of 1995. This report summarizes the findings of the Task Force as of April 8, 1996. While our task was to provide an in-depth look at the issues surrounding consideration of plastics recycling, there is more work to be done. The issue remains complex, and this report suggests the degree of analysis necessary to inform a sound decision about plastics recycling in the long term. We welcome questions and comments as we continue our research.

The increasing substitution of plastics for other types of packaging, such as glass and paper, has brought plastics disposal to the fore for the public, for recycling programs, and for elected officials concerned with solid waste management. The Berkeley Plastics Task Force conducted an investigation of the waste issue in the larger context of the full life-cycle of plastic – from production to use and through a number of disposal options. Our research included plastic manufacturing, the recyclability of various types of plastic packaging, the feasibility of picking up plastics in a curbside recycling program, and issues surrounding plastics in the waste stream.

Our goal was to produce a comprehensive report for decision-makers and the public. The Task Force will make the report available to all interested parties in Berkeley and elsewhere. We hope this report will:

- Illuminate the economic, health, and environmental costs and benefits of plastic packaging, including its production, use, and disposal by reuse, recycling, landfilling, and burning;
- Discuss the long-term and systematic impacts of existing and proposed plastic packaging practices, programs, and policies;
- Clearly and fairly compare the costs and benefits of alternative options for handling plastic packaging; and
- Stimulate public participation in deciding what to do about plastic packaging and how best to reach the City's goal of recycling 50% of its discards, mandated at the state and local levels.

Ecology Center staff and Board members were joined on the Task Force by representatives of Berkeley's recycling programs, the academic community, and other experts on environmental issues. The Task Force has consulted with environmental organizations, plastics industry experts, recycling program operators, solid waste management companies, and public agencies for information and comments on its findings.

To address your comments to the Task Force, please contact us at Attn: Plastics Task Force, Ecology Center, 2530 San Pablo Ave., Berkeley, CA 94702; 510-548-2220.

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REPORT OF THE
BERKELEY PLASTICS TASK FORCE

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1. WHAT PLASTICS ARE MADE OF AND HOW THEY ARE MADE

Plastic resin production

The raw material for all packaging plastics is ethylene. Ethylene is a gas derived from natural gas or from a fraction of crude oil that has a composition similar to natural gas. Both natural gas and crude oil are products of fossils and are therefore not renewable.

Producing and refining ethylene uses a lot of energy, requiring combustion to achieve high reaction temperatures and refrigeration to achieve extremely low temperatures to condense and separate gases (reaching about -260 degrees Fahrenheit). Largely because refrigeration is inherently mechanically inefficient, producing ethylene consumes at least 20 megajoules (MJ) per kilogram of ethylene produced.[1,2] Twenty MJ would run a 100-watt light bulb for 56 hours. Much of this energy is generated at the production site by burning some of the feedstock of natural gas or crude oil. Therefore, producing plastics for packaging uses nonrenewable resources to heat and refrigerate as well as feedstock. This is a resource use choice, because if the resource were not dedicated to making plastic packaging, it could be either conserved or used for other applications such as generating electricity.

Once ethylene has been produced, it is combined with solvents, co-monomers, additives, and other chemicals that will participate in the planned chemical reactions. The mixture is then subjected to a chemical reaction called “polymerization” that creates long-chain molecules. (“Mono” means “one” and “poly” means “many,” so a “monomer” is a single molecule — like ethylene — that can be bound with other molecules into a “polymer.”) The new polymer is extruded, pelletized, or flaked; the

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[1] A megajoule is one million joules, or 1 billion BTUs.

[2] *Kirk Othmer Encyclopedia of Chemical Technology*, Wiley, 1992.

product is called a "resin." Resin is sold, re-extruded, and made into containers, films, and other products.

Energy use compared – PET plastic vs. virgin and recycled glass

Since resin manufacturing consumes so much energy, making containers with plastic requires almost the same energy input as making containers with glass despite transportation savings that stem from plastic's light weight. The total energy required to produce, package, and transport a 16 oz. PET container is 32 MJ compared to 34 MJ for a 16 oz. glass container - virtually the same.[3] Producing a pound of plastic resin, however, uses nearly nine times the energy of producing a pound of glass.[4] These comparisons assume the use of virgin glass.

If the glass container uses recycled glass cullet in its feedstock, the energy required to produce it falls to less than 26 MJ for a 16-ounce glass container. That is 6 MJ less than what is needed for a new PET container.[5] Making the glass container with recycled cullet uses only 81% of the energy needed to make a plastic container.

Size of the virgin resin market

In 1995, about 32 million tons of plastic resin were produced in the US; about 39% of this amount, or 12.6 million tons, was used for packaging.[6] Only six resin types were used to make more than 92% of plastic packages.[7] Their names and common uses are shown in the following table:

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[3] Franklin Associates, *Comparative Energy and Environmental Impacts of Soft Drink Delivery Systems,* for the National Association for Plastic Container Recovery, March 1989.

[4] CSG/Tellus Packaging Study : "Assessing the Impacts of Production and Disposal of Packaging and Public Policy Measures to Alter its Mix : Volumes I and II," prepared for the Council of State Governments, US Environmental Protection Agency, and the New Jersey Department of Environmental Protection and Energy, Boston, MA, May 1992.

[5] Henry S. Cole and Kenneth A. Brown, "Advantage Glass!" prepared for the Glass Packaging Institute, Washington D.C., September 15, 1993, pp.124-126.

[6] *Modern Plastics International*, January 1996, pp.70-72.

[7] *Chemical and Engineering News*, July 4, 1994.

Table 1: Plastic Packaging; Resin Market Share; Uses

Chemical name	Abbr.	Resin code	1995 production (million lbs)	1995 (million tons)	% of plastic packaging	Typical products
polyethylene terephthalate	PET	1	3,920	1.96	15.6	soda and water bottles
high-density polyethylene	HDPE	2	5,410	2.71	21.5	milk and water jugs, laundry detergent bottles
polyvinyl chloride	PVC	3	520	.26	2.1	meat wrap
[linear] low-density polyethylene	LLDPE/ LDPE	4	7,030	3.52	27.9	grocery and trash bags
polypropylene	PP	5	1,610	.81	6.4	rigid containers
polystyrene	PS	6	4,620	2.31	18.3	fast food containers, meat and bakery trays
Total			23,110	11.56	91.7	

A number 7 on a plastic container indicates “other,” which typically means a combination of two or more of the six main resin types.

The use of plastics is increasing in almost all sectors of the economy, but the most rapid growth is in packaging. Globally, improved economic conditions tend to promote increased consumption and a corresponding increase in packaging. Analysts predict steady increases in the sales of most packaging plastics, particularly PET, for the foreseeable future.[8]

The advertisement of recyclability may contribute to increases in plastic packaging sales. *Modern Plastics International’s* January 1995 resin report explained that double-digit growth rates in PET consumption were due, in part, to “PET’s perceived environmental benefit in regards to recycling.”[9]

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8 Robert D. Leaversuch, “Resins ‘96,” *Modern Plastics International*, January 1996, pp.50-51.

9 Patrick A. Toensmeier, “Resins 1995,” *Modern Plastics International*, January 1995, p. 47.

New plastic packaging materials also contribute to plastics' market growth. The compositions of these new materials are varied and tailored to provide performance characteristics for specific applications.[10] Container shapes and sizes are becoming less standard and more numerous. But standardized container compositions and shapes facilitate sorting and reprocessing. Thus, the unlimited use of new materials, mixtures of materials, and a diversity of container shapes work against plastic reprocessing by making it more difficult and more expensive for collectors and processors to match their output to available markets.

2. THE PLASTICS INDUSTRY

The questions and issues surrounding plastics are influenced not only by the materials, but also by the structure and behavior of the industry that produces them. The plastics industry is powerful and prominent, and no discussion of plastics would be complete without considering its cultural and economic impacts as well as its technical characteristics.

Resin production and industrial concentration

Virgin plastic resin is produced by a small number of corporations. In 1995, for example, three corporations produced 94% of all PET resin.[11] Resin factories are large and streamlined to create a one-way flow of uniform product because of economy of scale. Because of their large size, these corporate producers control the choices available to manufactures and consumers.

Plastic resin factories are also concentrated geographically, mainly on the Gulf Coast, because the raw material ethylene is supplied mainly by pipeline. Resin customers, on the other hand, are widely dispersed. This geographic separation requires large amounts of energy for transportation, contributing to the intensive use of natural resources.

Recycled content

To increase the domestic market for post-consumer resources of all kinds, many governments have required manufacturers to use a certain

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[10] Doug Smock, "BASF Unveils New Styrenes for Computers, Packaging Films," *Plastics World,* Vol. 53, August 1995, p. 26. Also Robert D. Leaversuch, "BASF Readies Polymers Slate for Diverse End-Use Markets," *Modern Plastics International,* Vol. 72, August 1995, p. 69.

[11] Ibid., p.63.

percentage of reclaimed material in their feedstock. Plastics are no exception to this trend. Oregon, for example, produced a flurry of research and development in plastics when its legislature required 25% recycled content in plastic containers. Such legislation recognizes that although recycling does not reduce energy use or emissions to the degree that reuse does, mandating recycled content sets forces in motion that will replace virgin material with reclaimed resources, so long as the recycled content comes from post-consumer bottles or packaging and not from in-house manufacturing scrap.

In general, recycled-content laws partially close the materials-flow loop and help foster consideration of the full life-cycle of products. By recycling, plastic manufacturers take some degree of responsibility for the fate of the materials they produce. California's SB235 and SB2092 are examples of mandatory content legislation that require, respectively, 25% and 30% reprocessed post-consumer plastic contents in a narrow class of plastic containers and trash bags.[12]

The direct effect of recycled-content legislation is on manufacturers of containers and plastic film, not on resin producers. However, for recycled-content containers to perform adequately, the virgin and recycled materials must be compatible. The technical interchange required to assure compatibility requires virgin-resin manufacturers to make manufacturing decisions that benefit the makers of recycled-content containers.

The virgin-plastics industry has resisted such cooperation by strongly opposing recycled-content legislation, and has defeated or weakened efforts to institute stronger laws in Oregon and California. According to Senior Editor Victor Wigotsky of *Plastics Engineering* magazine, the two largest plastic technology consortiums — the American Plastics Council and The Society of the Plastics Industry — have made a concerted effort to “assure a measure of restraint and reason in the drafting of packaging legislation” and to “oppose the passage of some 180 restrictive legislative proposals in 32 states.”[13]

This behavior suggests that the bigger their share of the packaging market, the more forcefully virgin-plastic manufacturers will oppose recycled content laws.

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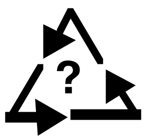
[12] California Public Resources Code, Title 14, Division 7, Ch. 14, Sections 17942-49 and 17975-85.

[13] V. Wigotsky, “To Market To Market,” *Plastics Engineering*, June 1995, p. 16.

Chasing arrows and the resin code

Most plastic containers and many other plastic products are now imprinted with a number that represents the type of plastic used, as previously noted in Table 1. This number appears inside a triangle of chasing arrows as shown below, and the resin's initials are usually stamped below the symbol. This usage first appeared in 1988 when The Society of the Plastics Industry (SPI) appropriated the chasing arrows, a universal symbol of recyclability developed and used by the recycling industry. After incorporating the chasing arrows into this label, the SPI promoted this usage aggressively. Within the USA, this labeling has been institutionalized by state governments and is now required by 39 states. It is also widely used internationally.



But although SPI's use of the chasing arrows with the resin code may be good for the plastics industry, it has been very costly and irritating to recycling collectors. The public sees the chasing arrows and assumes not only that anything stamped with them is technically recyclable, but that local collectors and processors can handle them. People then discard all grades of coded plastics into the same recycling bins. The recycling collector, however, sees much of this material as contamination, since there is often no infrastructure for taking the material back, let alone paying for it once it is cleaned and separated. The result is a new category of waste known as "residue." Residue is a major cost problem for materials recovery operators, particularly those with multiple-materials recovery facilities.

Aside from the misleading arrows, the industry's code numbers confuse the public into mixing containers that can't be processed together. For example, blow-molded and injection-molded HDPE bottles have different melting behaviors, so they cannot be processed together into a high-quality recycled material. Consumers sometimes blame recyclers if they try to contribute to the recycling effort but are told a program cannot accept their containers.

In its Fall 1988 "COPPE Quarterly" newsletter, the Council on Plastics and Packaging in the Environment (an industry group and predecessor to APC) acknowledged that the legislatures in Florida, Minnesota, and Wisconsin adopted the coding system "as an alternative to more stringent legislation."[14] One COPPE news story discussed an editorial in *The New York Times* about the decision made in Nassau County, New York to ban some plastic containers to save landfill space. This voluntary coding

[14] Council on Plastics and Packaging in the Environment, *COPPE Quarterly,* Volume 2, Number 4, Fall 1988, Washington, DC, pp. 1,3.

system for resin identification was an alternative that seemed acceptable at the time.

Since the code is unclear and misleading, recycling trade groups and even governments have made attempts to modify the symbol, starting in the fall of 1988. The plastics industry's continuing resistance to changing the code suggests that the symbol's lack of clarity benefits plastic sales. Attempts to modify the code in California, the state of Washington, and Colorado were defeated by the campaigns and lobbying efforts of APC and its industrial allies.[15] Negotiations in 1993 between SPI and the National Recycling Coalition intended to resolve the coding issues ended with no action to clarify the misleading labeling.

On the other hand, the plastics industry and the APC in particular have put big money into a public relations campaign to convince the public that plastics recycling is easy, economical, and a big success. Between November 1992 and July 1993, the APC spent $18 million in a national advertising campaign to "Take Another Look at Plastics." While trumpeting large numbers of pounds of plastic recycled, they neglected to point out that in the year cited, 1993, 15 billion pounds were produced but only 1 billion pounds recycled. The Environmental Defense Fund, which released these figures, found that the small increases in recycling "did not even come close to keeping up with increased production of virgin plastic over the same period."[16] (See Figure 2) The plastics industry promotes recycling to breed public support in the market for plastic products and packaging.

3. OVERALL IMPACT OF PLASTICS ON THE ENVIRONMENT, WITH AN EMPHASIS ON CONTAINERS

Pollution and hazards from manufacturing

The most obvious form of pollution associated with plastic packaging is wasted plastic sent to landfills. Plastics are very stable and therefore stay in the environment a long time after they are discarded, especially if they are shielded from direct sunlight by being buried in landfills. Decomposition rates are further decreased by anti-oxidants that

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[15] Wigotsky, op. cit.

[16] Environmental Defense Fund, "Yet Another Look at Plastics Recycling," September 12, 1994.

manufacturers commonly add to enhance a container's resistance to attack by acidic contents.

Plastics also put a big chemical burden on the environment. The Oakland Recycling Association commissioned an analysis of the toxic chemical burden that relied heavily on information from EPA data, especially the Toxics Release Inventory.[17] These data were limited because manufacturers within the "miscellaneous plastics sector" did not file reports. Nevertheless, the information available showed that most toxic releases went into the air, and the plastics industry contributed 14% of the national total. Of the top ten manufacturers ranked by total releases, seven made plastic foam products. Significant releases of toxic chemicals included :

- trichloroethane
- methylene chloride
- styrene
- benzene
- acetone
- methyl ethyl ketone
- toluene
- 1,1,1 trichloroethane

Other major emissions from plastic production processes include sulfur oxides, nitrous oxides, methanol, ethylene oxide, and volatile organic compounds.[18]

Less visible but very serious is the pollution generated by producing plastic resin. As ethylene is polymerized, the reactive mixture is scrubbed with dilute aqueous caustic solutions[19] that become high-volume pollutants. The refining process uses waste-minimization methods, but point-source air emissions are still high because of inherent difficulties in handling large flows of pressurized gases. Manufacturing PET resin generates more toxic emissions (nickel, ethylbenzene, ethylene oxide, benzene) than manufacturing glass. Producing a 16 oz. PET bottle generates more than 100 times the toxic emissions to air and water than making the same size bottle out of glass.[20]

Producing plastics can be hazardous to workers, too. Serious accidents have included explosions, chemical fires, chemical spills, and clouds of toxic vapor. These kinds of occurrences have caused deaths, injuries,

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[17] *Developing Local Markets for Post-Consumer Rigid PET and HDPE Containers in the East Bay*, Oakland Recycling Assn., Oakland, CA, 1995.

[18] CSG/Tellus Packaging Study, op.cit.

[19] *Kirk Othmer Encyclopedia of Chemical Technology,* Wiley, 1992.

[20] CSG/Tellus Packaging Study , op.cit.

evacuations and major property damage.[21] A review of the US EPA's data base of 10,000 accidents and spills from 1980-87 shows that nearly 1,600 (16%) of industrial accidents were associated with producing plastics or plastic constituents.[22]

Negative health effects – toxic additives, migration into food

In addition to creating safety problems during production, many chemical additives that give plastic products desirable performance properties also have negative environmental and human health effects. These effects include direct toxicity, as in the cases of lead, cadmium, and mercury; or carcinogens, as in the case of diethyl hexylphosphate (DEHP). Problem chemicals are used as plasticizers, antioxidants, colorants, flame retardants, heat stabilizers, and barrier resins. A single resin type might be mixed with many such additives, adding complexity to the chemical composition and possibly generating new classes of incompatible resins within the grossly simplified SPI resin code. An example of internal incompatibility is resin type 2, noted earlier as a recycling problem because the blow-mold resin grades and injection-mold grades must be separated for most primary recycling applications.

People are exposed to these chemicals not only during manufacturing, but also by using plastic packages, because some chemicals diffuse (migrate) from the packaging polymer to the foods they contain. Migration potential exists for traces of monomers, oligomers, additives, stabilizers, plasticizers, lubricants, anti-static nucleating agents, and reaction products of the polymer or its additives. Such substances may be toxic.

Examples of plastics contaminating food have been reported with most polymers, including styrene from polystyrene, plasticizers from PVC, antioxidants from polyethylene, and acetaldehyde from PET.[23] Among the factors controlling migration are the chemical structure of the migrants and the nature of the packaged food.[24] In studies cited in *Food Additives and Contaminants*,[25] LDPE, HDPE, and polypropylene bottles released

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[21] Henry S. Cole, op.cit., pp.74-7.

[22] US EPA, Final Report, Acute Hazardous Events Data Base, 1989.

[23] "Male Reproductive Health and Environmental Chemicals with Estrogenic Effects," Danish Environmental Protection Agency, Copenhagen, Denmark, April 18, 1995.

[24] Alexandre Feigenbaum, Anne-Marie Riquet, and Violett Ducruet, "Safety and Quality of Foodstuffs in Contact with Plastic Materials," *Journal of Chemical Education*, November 1993.

[25] Piringer, O.G., "Evaluation of Plastics for Food Packaging," *Food Additives and Contaminants*, Vol. II, No. 2, 1994.

measurable levels of BHT, Chimassorb 81, Irganox PS 800, Irganix 1076, and Irganox 1010 into their contents of vegetable oil and ethanol. Evidence was also found that acetaldehyde migrated out of PET and into water.

Diverting solid waste

Curbside plastic collection programs are driven in part by a wish to minimize municipal solid waste. Indeed, most legislation dealing with discarded containers has focused on creating mechanisms that would divert municipal plastic waste from incinerators or landfills. These initiatives include container deposit laws and landfill use-reduction laws. Although important, such measures do not solve the problem of over-packaging or reduce the production of plastic packaging. Only source reduction can do this. As discussed in section 8, Germany recognized the need to implement aggressive source reduction and passed a law requiring all manufacturers to arrange to pick up discarded packaging, usually at the point of sale, such as the supermarket. This requirement has encouraged industry to reduce packaging.

In addition, as noted earlier, providing recycling for plastic containers may actually encourage their use and increased production. But as plastic packages become less standardized and more complex, recycling becomes more difficult. Already, many plastic packages that consumers have expected to be recycled must be landfilled. Therefore the diversion may not be as effective as proponents intend. (See misconceptions 1 and 2 in section 10 below.)

4. REUSING PLASTIC CONTAINERS

Reusing containers is one of the most effective and inexpensive ways to reduce the environmental impact of packaging. Some plastic containers can be made durable enough to be refilled and reused about 25 times before becoming too damaged for reuse.[26] Refilling and reusing plastic containers directly reduces the demand for disposable plastic. Accordingly, lowering demand for single-use containers reduces waste and energy consumption. Based on 1990 data, if glass and PET bottles were refilled and reused 25–35 times, the overall weight of beer and soft drink container waste would be reduced by 73.6%.[27] Significant reductions in waste and energy consumption can be achieved with just 7–8 reuses of a single bottle.

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[26] Saphire, David, *Case Reopened: Reassessing Refillable Bottles*, INFORM, NY, 1994.
[27] Ibid.

One toxicity study investigating the use of PET for refillable bottles tested various toxic substances to see if they would be absorbed into the PET plastic during one use, then released in the next use. After test substances were removed and the plastic washed, the bottles were filled with food, and the contents were analyzed. The analysis showed that none of the test substances was absorbed into the PET. This study concluded that PET could be considered as a practical candidate for refillable containers.[28] As discussed above, migration of additives from the PET itself is still a problem.

Reusing glass containers was standard procedure in this country through about the 1950s, and there are still a few products distributed in reusable containers. For example, milk is sold in both plastic and glass containers that have been washed and refilled. However, with a long history of proven performance, glass remains the most practical candidate for reusable containers.

5. REPROCESSING PLASTICS

Recycled plastic products – a hierarchy of uses

Materials collected and processed as recyclables rarely come back from manufacturers as the same product. Some uses seem superior to others, a sentiment expressed by the phrase “highest and best use,” which used to refer primarily to energy conservation but now is used more broadly. Referring to resources, some uses directly reduce demand for virgin materials, whereas others essentially create unneeded products that do nothing to reduce the consumption of virgin materials. Many recycled-content products are themselves essentially unrecyclable. Based on these kinds of considerations, at least three different product outcomes can be observed, namely, primary, secondary, and tertiary reprocessing.

As applied to plastic packaging, primary reprocessing produces new packaging; secondary reprocessing produces new items that are usually not practically recyclable themselves because of reduced polymer purity and the lack of collection infrastructure; tertiary reprocessing uses high heat or industrial chemicals to break plastic products into their chemical components, some of which can then, in theory, be made into new products.

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[28] Feron, V.J., et.al., “Polyethylene Terephthalate Bottles: a Health and Safely Assessment”, *Food Additives and Contaminants*, Vol. II, No. 5, 1994.

Primary reprocessing

This entails remanufacturing the recovered product back into the same product. An example is recovered aluminum cans made into new aluminum cans, or a recovered clear glass bottle made into a new clear glass bottle.

In theory, all six of the six resin types used to make packaging plastics are candidates for primary reprocessing. In reality, however, primary reprocessing is rare.

Two chemical properties make it difficult. One is plastic's sensitivity to heat and handling. Plastic molecules are long and flexible, and they change structurally when subjected to thermal and mechanical stress during melting and extrusion. The molecules interconnect and stiffen, and the plastic becomes weak and brittle. This type of degradation is called "heat history" in the plastics recycling trade. The deterioration accumulates with each reprocessing and is irreversible. In contrast, glass and aluminum, composed of short, robust molecules, are not as sensitive to heat and handling and therefore can be reprocessed many times.

The second chemical property that makes primary reprocessing difficult is that plastics are very susceptible to contamination. If sorting is imperfect, resins may mix with other kinds of organic debris when melted. Mixing leads to defects and disruptions in the molecular structure which, in turn, leads to degraded properties. In some cases, contamination leads to the total breakdown of the polymer. For example, even trace amounts of polyvinyl chloride (PVC) destroy polyethylene when the two are melted together.[29]

An analogous problem is found with glass, which is highly sensitive to ceramic contamination. With plastics, however, potential contaminants are more plentiful and much more difficult to control. Separating plastics is particularly problematic because there is little variation in physical properties (such as density and solubility) to use in sorting. Also, the six basic types of plastic resin include multiple grades and colors within each resin type, and often several resin types are used to make a single container.

Primary plastics reprocessing is therefore strongly limited by the chemical properties of the material. Reprocessors that make plastic containers out

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[29] Giannotta, Giorgio, et.al., *Processing Effects on Poly(Ethylene Terephthalate) from Bottle Scraps*, Polymer Engineering and Science, v34, August 1994, pp. 1219-23.

of other plastic containers typically blend virgin resin with the recycled resin to boost the product's performance. One study reported that it is possible to make containers with recycled contents of up to 50%, if the reclaimed containers used are themselves made of pure virgin resin.[30] At least one blow-molder was also able to produce a 100%-recycled content bottle with the desired properties using a particular blend of post-consumer resins.[31] However, large-scale reprocessors have found that using more than 15% to 25% of post-consumer feedstock reduced the strength of their containers.[32]

Secondary reprocessing

This is the most common type of plastic reprocessing in the USA. It uses recovered plastics to produce new items that are usually not recyclable themselves. Secondary reprocessing reduces the quality of the polymer if it reduces its purity. Accordingly (and largely theoretically, since the industry is very new), feedstock does not have to be as pure as for primary reprocessing. Principal products made by secondary reprocessing include textiles, panels, pallets, and plastic lumber.

Secondary reprocessing sometimes diverts material from landfill and sometimes decreases the use of virgin material. For example, if there is a market for a jacket filled with polyester fiber, and that jacket's filling is made from post-consumer bottles, then the bottles are diverted from landfill and the virgin resources that otherwise would have been used to make the fiber are conserved.

In plastics recycling, secondary reprocessing differs from primary in the following respects:

- It reprocesses materials in such a way as to render them less recyclable or unrecyclable;
- It is less likely to be the highest and best use; and
- It does not usually reduce the production of plastic packaging from virgin resources.

A comparison of the material flows for alternative plastic disposal schemes (reuse, primary, secondary reprocessing) is shown below.

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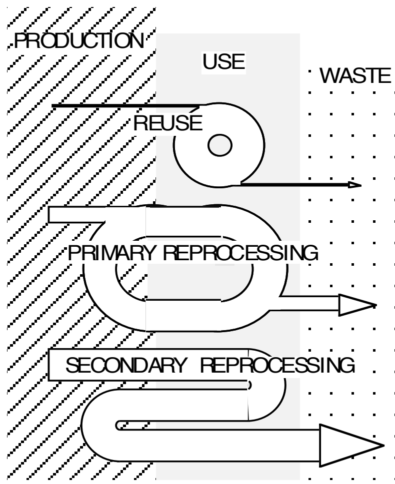
30 Brewer, Gretchen, *Plastic Remanufacturing Company Profiles*, Oakland Recycling Association, Oakland, CA, 1995. pp.11-13.

31 "Plastics Manufacturing Process Assessments", ReTAP Technology Brief, Clean Washington Center, Seattle, WA, 1994.

32 "Toughing Out the Plastics Crunch," *World Wastes*, February 1995.

Primary and secondary schemes take material back into the "production" section for the reprocessing operation. All three schemes are based on the same volume of use indicated by the thickness of the material flow arrows in the "use" section. The amount of material produced and wasted increases going from reuse to primary to secondary reprocessing. An interesting point shown in the figure is that secondary reprocessing (the most common type of plastic reprocessing in the US) does not form a closed loop.

Figure 1: Comparison of Material Flows with Alternative Disposal Schemes



Tertiary reprocessing

In tertiary reprocessing, plastics are broken down into basic chemicals that could be reconstituted into virgin-grade material or used as fuel. Converting the output from tertiary processing back into ethylene for plastic synthesis uses cryogenic (low temperature) separation.[33] The process is very similar to producing ethylene from natural gas.

In theory, tertiary reprocessing permits mixed collection without the extensive sorting and cleaning required by primary and, to a lesser extent, secondary reprocessing. However, since tertiary processes are functionally similar to chemical manufacturing, the environmental impacts, including emissions and energy use, are likely to be high compared to primary or secondary reprocessing. Tertiary is not widely practiced in the US because of the high capital and operating costs of the process.

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33 W. Kaminsky, op.cit.

Tertiary reprocessing of plastics has been done using thermal and chemical methods. Chemical processes, including glycolysis, methanolysis, and hydrolysis, decompose plastic by unzipping the polymer chains. Thermal processes, primarily pyrolysis, use heat and catalysts to break plastic down into gases such as ethane and methane. Current thinking is that thermal processing is the only commercially viable type of tertiary reprocessing, since only PET among the packaging resin types can be processed by chemical methods.[34]

The pyrolysis process requires using a large stream of purified inert gas, typically nitrogen, to prevent the plastic from completely decomposing through combustion into carbon dioxide and water. The process requires substantial energy input, since plastics are poor thermal conductors. When clean, pure polymer feed streams are processed under laboratory conditions, pyrolysis generates up to 10% waste material, including coke and often hazardous inorganic compounds.[35] This result suggests that under production conditions, with grossly mixed and contaminated feedstocks, the residue may be substantially higher. On the other hand, some tertiary reprocessors in Germany have claimed they have reduced residual material to 5% of what came in. This level is commendably low by conventional refining or remanufacturing operation standards. The residues of existing tertiary processes are landfilled.[36]

Marketing recovered plastics

While recycling proportions are high for some container types in the US, so far plastic recovery has had only a minor impact on the total amount wasted. The EPA estimates that in 1993, 22% of all discards were recovered. Recovery rates were more than 30% for paper and 60% for metal. But only 3.5% of discarded plastic was recovered.[37]

Most of the plastic packaging that is recovered and reprocessed comes from PET and HDPE bottles. Other plastic resin types are reprocessed at rates that hover around 1%. In 1995 reprocessed resin consumption

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34 Suzanne Shelley, "Plastics Reborn", *Chemical Engineering*, v99, July 1992, pg.30.

35 W. Kaminsky and H. Rossler, "Olefins from Wastes," *Chemtech*, February 1992, p.108.

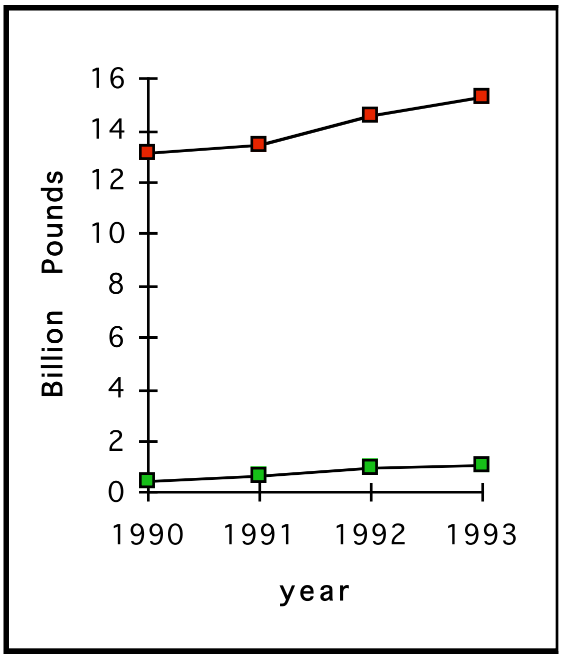
36 The purpose is to remove H_2S and CO_2 to reduce acid gas emissions. See Philip Goldsmith, "Cracking the Plastic Poser," *Process Engineering,* v75, April 1994, pg.29.

37 US Environmental Protection Agency, *Characterization of Municipal Solid Waste in the United States : 1994 Update, Executive Summary,* November 1994, p.30.

totaled 1,525 million pounds, or about 2% of the total plastic resin used.[38]

Figure 2 below shows the dramatic disparity between the growth in production of virgin resins and production of recycled resins.[39] Using APC data, the Environmental Defense Fund found that the virgin market grew more than 6 times faster than the recycled market.[40]

Figure 2: Plastic Packaging Produced and Recycled, 1990-1993



The market for products of secondary processing has been limited both by product performance problems and high material costs. Plastic lumber, for example, is heavy compared to wood, cannot be used to bear loads in structures, is subject to warping, and begins to degrade when exposed to sunlight. Recycled HDPE pellets cost \$0.34/lb, almost as much as the \$0.38/lb price for virgin HDPE. Recycled PET pellets cost about \$0.58/lb

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38 *Modern Plastics International*, January 1996, pp.70-72.

39 US Environmental Protection Agency, op.cit., p.30.

40 Environmental Defense Fund, “Yet Another Look at Plastics Recycling,” September 12, 1994.

compared to $0.76/lb for virgin material.[41] Economic return is reduced by the high price of recycled resin and the practical requirement to use at least 50% virgin resin to achieve desired performance.

Domestic and international destinations of recovered materials

After plastic containers are collected (those economic considerations will be discussed later), they must be sold, reprocessed, and made into new products.

The market in post-consumer resin is dominated by a few large plastic-reprocessing facilities in the US and by Pacific Rim countries. Both can pay high prices for the post-consumer resource, the first because of automation[42] and the second because of low labor costs for sorting.[43] Nationally the amount of post-consumer plastics exported is at least 20% to 30%. The state of Oregon, for example, exports about 35% of its plastic scrap.[44] In California, all recovered PET goes to the Plastic Recycling Corporation of California (PRCC). In 1995 the PRCC sold nearly all of California's recovered PET overseas.[45]

This market structure creates several impacts worth noting. First, California businesses that use recycled PET resin must purchase it out of state.[46] Therefore, the development of local businesses using recycled plastic resin is inhibited,[47,48] and this new round of transportation uses more energy and generates more pollution.

In addition, plastics are a major component of an international trade in discarded resources that has become a source of serious problems. Discarded materials that are collected in industrialized countries and shipped to third-world countries as recyclables are sometimes badly contaminated. Occasionally the contamination is hazardous waste. The countries that ship the materials rely on the often-weak regulatory climates, huge reservoirs of cheap labor, and desperate economies of the

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[41] *Plastics News,* January 1996.

[42] *Plastics News*, April 1995.

[43] *Developing Local Markets for Post-Consumer Rigid PET and HDPE Containers in the East Bay*, Oakland Recycling Association, Oakland, CA, 1995.

[44] "Plastics Recycling Update," *Resource Recycling*, v8, No.11, November 1995.

[45] *Developing Local Markets ...*, op.cit.

[46] *Secondary Materials Market Assessment Study*, California Integrated Waste Management Board, Sacramento, CA, 1994.

[47] Jack Migrom, *Trends in Plastic Recycling*, Resource Recycling, p.75, May 1994.

[48] *Developing Local Markets ...*, op.cit.

receiving countries. Greenpeace and other organizations have documented conditions at recycling facilities in countries that import this material and have found conditions to be hazardous and exploitive. In addition, Greenpeace found that exported plastics were very poorly sorted. In a seven-country survey, up to 50% of the discards shipped overseas were contaminated and had to be dumped, often in unlined, unmanaged sites.[49] Little or no documentation has been found regarding the market stability or soundness of the products that these countries produce with plastic scrap. The "cradle to grave" approach to waste management does not apply if the "grave" is in another country.

6. PLASTICS IN THE DISCARD STREAM

National discard stream composition estimates

With the increase in plastic production and use, more plastics are discarded. A 1994 EPA study of the national supply of discards[50] says that in 1970, plastics composed less than 3% by weight of the municipal supply. By 1986, they had risen to 6%.

For 1993, the EPA estimates that the US burned or buried 207 million tons of discards or 1,600 pounds per person.[51] Their composition estimate for the discard stream is represented in the following table[52] :

Table 2: Composition of the US Municipal Discard Stream, 1993

Material Type	Discarded (million tons)	Percent of Total
Paper and Paperboard	77.8	38
Food and Yard Trimmings	49.7	24

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[49] Greenpeace research cited in "Plundering the Planet: Full Speed Ahead," *Multinational Monitor*, p.8, September 1994.

[50] EPA, op.cit., p.31.

[51] 1993 estimated U.S. population of 257,783,000 people from the Statistical Abstract of the U.S., U.S. Bureau of Census, 1995.

[52] Some believe that the EPA's methodology, as applied by perennial contractor The Franklin Institute, systematically overstates wasting because it pays more attention to production than actual landfilling, excludes certain kinds and classes of recycling from measurement, and defines as wastes many things that are actually recovered for recycling.

Plastics	19.3	9
Metals	17.1	8
Wood	13.7	7
Glass	13.7	7
Other	15.7	7
Total	207.0	100

Of the estimated 19.3 million tons of plastics burned or buried in landfills, 8.1 million tons, or 63 pounds per person per year, was plastic packaging materials.

In states where beverage containers have redemption or deposit value, the proportion of these containers in the garbage has dropped significantly. For example, an estimated 28% of all PET bottles sold in the US is recovered,[53] and 90% of those came from states with bottle bills or mandated deposits.[54] Nevertheless, even as plastic reprocessing rates have increased, the amount of virgin resins produced has risen much faster.

Berkeley, CA discard stream composition estimates

A study of Berkeley, California's waste stream, which totaled 100.4 thousand tons after diversion in 1991, showed the following major components:[55]

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53 R.W. Beck and Associates, *1993 National Post-Consumer Plastics Recycling Rate Study*, Seattle, June 1994.

54 *Plastics Recycling - Problems and Possibilities*, Hearing before the Subcommittee on Environment and Employment of the Committee on Small Business, US House of Representatives, 102nd Congress, no.57, 1992.

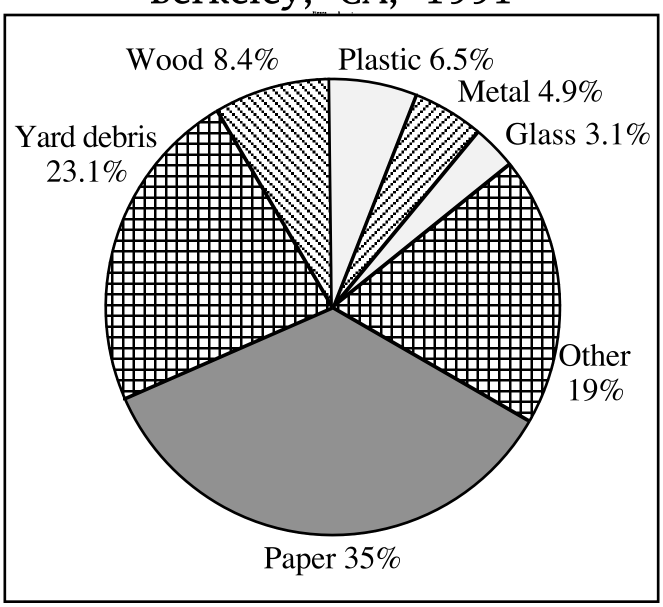
55 Cal Recovery Systems study for the City of Berkeley, Berkeley, California, 1991.

Table 3: Composition of Berkeley's Municipal Waste Stream, 1991

Material Type	Amount Wasted (thousand tons)	Percent of Total
Paper and Paperboard	35.2	35.0
Yard Trimmings, Food	23.2	23.1
Wood	8.4	8.4
Plastics	6.5	6.5
Metals	4.9	4.9
Glass	3.1	3.1
Other	19.1	19.0
Total	100.4	100.0

The quantity of plastic in the Berkeley waste supply is compared with the quantities of other materials in the pie chart below.

Figure 3: Waste Composition After Diversion, Berkeley, CA, 1991



Of the plastics discarded in Berkeley in 1991, almost 47% was film plastics such as bags and wrapping, and 43% was mixed plastics including polystyrene foam. Seventy tons was PET, and 582 tons was HDPE. Since PET and HDPE are the only plastic resins that have accessible markets, this means that only 10% of plastic discards or less than 1% of Berkeley's total waste stream would be targeted for recycling. As will be discussed in the following section, a curbside collection program could capture only a fraction of this target material.

7. COMPARATIVE COLLECTION COSTS AND BENEFITS IN BERKELEY, CALIFORNIA

Now that a context of industrial considerations and the projected supply in Berkeley has been set, finances and collection mechanics can be considered. Adding plastic containers to the curbside collection program in Berkeley would necessarily add costs in operations and in other areas, including a public education program to tell residents about the change. Operational costs may be incurred for new collection equipment, expanding processing facilities and storage capacity, added labor, and other increased operating expenses.

Possible benefits could include income, diverting more material from landfill, conserving more resources and energy, providing an opportunity for local economic development, and increasing customer service and satisfaction.

The balance of costs and benefits is the subject of the following analysis, which examines the question of beginning curbside recycling collection of plastic bottles made of PET (soda and custom), and natural HDPE (milk and water jugs) in Berkeley.

Estimated amounts available for collection in Berkeley

To assess costs and benefits, we must project how much material curbside collection could divert from landfill. As previously noted, research conducted for a 1991 study showed that Berkeley landfilled more than 650 tons of PET and HDPE.[56] This figure provides only a point of reference because plastic packaging use and disposal has increased significantly since 1991. Also, the study gives no information on the sources of the material or the types of articles included in the categories. For example, the common five-gallon plastic pail used for commercial quantities of food and construction products would be included in the composition study as HDPE, but is not a target material in this analysis.

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56 Ibid.

To respond to the Berkeley City Council's January 1995 request for a plastics recycling plan, staff of the City's Refuse and Recycling Division, the Ecology Center, and Community Conservation Centers developed estimates of the quantities of plastic bottles that could be collected for recycling. The organizations used several sources of information, including a 1995 report from the American Plastic Council, the Plastics Recycling Plan for San Diego County, and information from other cities. The tonnage projections the three groups developed varied only slightly and can be fairly represented as follows:

Table 4: First Estimate of Plastic Bottles Available in Berkeley

Program	PET (tons/year)	HDPE (tons/yr.)
Dropoff	6	32
BuyBack	12	
Curbside	26	134
Commercial	6	34
Totals	50	200

<u>The estimated quantity of plastic bottles that could reasonably be captured for reprocessing represents less than one-half of 1% of the municipal waste stream.</u>

How we projected the costs of adding plastic containers to the curbside program

The costs for adding any material to the recycling system in Berkeley should be considered in terms of both incremental and allocated costs. Incremental costs are all the extra expenses necessary to collect, process, and market the new material. Examples of incremental costs are special equipment such as compactors, additional collection trucks and crews, new educational materials, and publicity. Analyzing incremental costs is helpful in deciding what the budgetary effect will be of adding a new material to the collection service.

Allocated costs are the ongoing operational costs of collection, sorting, baling, etc., assigned to each material handled by the program. Allocated costs are usually expressed in dollars per ton, even though allocations may be based on various complicated factors such as time required for collection or percent of volume occupied in the collection truck. Allocated-cost analysis provides a basis for comparing the costs of collecting plastic containers with the costs of collecting other materials.

The difference between incremental and allocated costs can be illustrated this way: if adding a material requires buying a new baler and adding one person to the payroll, the purchase and added staff are incremental costs. But when the baler is up and running, if it processes three existing materials in addition to the new one, allocating the costs would divide the operating costs among both new and existing materials according to how much cost they incurred in baler time and maintenance. Similarly, adding a new staff person may be an incremental cost. But once he or she is on the payroll, the total staffing costs can be allocated among the new and existing materials according to the labor they require.

Incremental and allocated costs of adding plastic bottles to Berkeley recycling programs

Community Conservation Centers (CCC) accepts PET and natural HDPE bottles at both its recycling centers and purchases California redemption value PET at The BuyBack. Although some capital costs must be incurred to increase storage capacity and security, CCC found that market prices in early 1995 were high enough to cover the costs of processing and marketing the bottles.

The City of Berkeley's commercial collection program has been collecting plastic bottles from 45 bars and restaurants for several months. The program collects several hundred pounds of plastic each week, mostly HDPE. (Note: most of this report calculates materials in tons, not pounds.) In 1995 City staff estimated that the only additional cost to add plastics to all commercial collection accounts would be one-half fulltime-equivalent (FTE) collection worker. City staff has recently revised estimated tonnage from the commercial program to include service to 9,000 apartment households in large buildings, more than a hundred food service establishments, and 500 other buildings. Estimates for the expanded program are 21 tons of PET and 50 tons of HDPE annually.

Processing costs must also be considered. CCC processes materials from the City and the Ecology Center, and to expand commercial collection or begin residential curbside collection of plastic bottles, CCC's current sorting system for glass and cans must be improved. CCC estimates the capital costs for these improvements at $64,100. CCC also estimates that one additional sorter will be needed to sort the tonnage projected for both the commercial and curbside programs. Additional costs must be also be considered for handling, perhaps baling, and transporting bales or unbaled containers to local buyers. CCC has estimated the incremental costs for adding sorting personnel, baling time and supplies, shipping, and overhead to be more than $200 per ton. The estimate was based on sorting 194 tons annually of two types of plastic from loads of mixed bottles and cans.

Accurately forecasting the volume of plastic expected to be set out for collection is critically important for the curbside collection program. Enough truck capacity must be provided to handle the new material as well as the increase in participation that normally occurs after a fresh public education program. The anticipated weight and volume depend on a number of factors such as the market share of plastic compared to other container types, whether they have deposit or redemption value, and demographic profiles of the neighborhoods served.

The American Plastics Council (APC) conducted extensive research on plastic-bottle recycling from 1992 to 1994 and published their results in a 1995 report, *How to Collect Plastic for Recycling.*[57] The APC studied curbside and dropoff programs across the country and collected extensive data on how many plastic bottles were available and set out for recycling. Three of the programs studied were in states with beverage container redemption or deposit legislation ("bottle-bill" states): San Francisco, California; West Linn, Oregon; and Springfield, Massachusetts. This report will use the results from San Francisco and the average for the three bottle-bill states to model a collection program for Berkeley.

The APC study found the following "generation rates," which include amounts found in household recycling bins and garbage cans but exclude bottles discarded away from home or taken to recycling or redemption centers.

Table 5: Plastic Bottle Generation Rates

	San Francisco (lbs/household/yr)	Bottle Bill States (lbs/household/yr)
PET soda custom	1.3 2.8	1.1 2.4
Total PET	4.1	3.5

[57] American Plastics Council, *How to Collect Plastic for Recycling,* 1995.

Natural HDPE*	5.7	12.6
Total, PET and HDPE	9.8	16.1

*Milk and soda jugs.

San Francisco had significantly less natural HDPE than any other city in the study. The APC suggests that this might be due to the nature of the sampled routes, and that perhaps fewer families had small children.

A rough estimate of the tonnage available for collection can be obtained by applying the following calculation:

> tonnage available = (the number of households served by the program) x (the generation rate in lbs/yr) x (the participation rate) x (the capture rate) / (2000 lbs/ton).

The participation rate is the percentage of households that participate in the program at least once a month. The capture rate is the percentage of the materials that are actually set out for curbside recycling and not tossed in the trash or taken to a recycling center. Of course, generation, participation, and capture rates vary due to a great number of factors including family size, education and promotion campaigns, and collection methods.

The APC study recorded an average participation rate of 71% in the six study programs, and capture rates for HDPE and PET were about 65%. The Ecology Center's curbside recycling program serves about 35,000 households residing in single-family and multi-family buildings up to nine units. Using the generation and participation rates found by the APC study, the calculations are:

San Francisco used as basis

(35,000 households) x (9.8 lbs/yr) x (71% participation) x (65% capture) / 2000 lbs/ton = **79 tons/year capturable in Berkeley**

Bottle Bill States Average used as basis

(35,000 households) x (16 lbs/yr) x (71% participation) x (65% capture) / 2000 lbs/ton

= **129 tons/year capturable in Berkeley**

These calculations can be further refined by using the capture rates for each bottle type. These are: 48% for custom PET, 60% for soda PET, and

70% for natural HDPE. The resulting tonnages are shown in the following chart:

Table 6: Second Estimate of Plastic Bottles Capturable in Berkeley

	Basis: San Francisco (tons/yr)	Basis: Bottle-Bill States Average (tons/yr)
PET soda	9.7	8.2
custom	16.7	14.3
Total PET	26.4	22.5
Natural HDPE	49.6	109.6
Total, PET and HDPE	**76.0**	**132.1**

The PET tonnage is lower than the estimate of 50 tons made in 1995 by the Ecology Center, CCC, and City staff. The HDPE tonnage is considerably lower than the 200 annual tons first estimated. Until a better estimate is available, the bottle-bill states' average of 132.1 tons will be assumed to approximate the tonnage of plastic bottles available for collection in Berkeley.

To gain a fuller understanding for good program planning, however, we need not just an average tonnage, but an anticipated range for both tonnage and volume. **For reference, we will set the anticipated HDPE tonnage range at a low of 76 tons per year and a high of 160, with an average of 132.** Now the volume of the materials must be found.

The APC study found the average density of materials set out for curbside collection to be 32 pounds per cubic yard for PET (soda and custom) and 20 pounds per cubic yard for natural HDPE. For the anticipated annual tonnage, the collection program would be expected to pick up a low of 25.5 cubic yards, a high of 58 cubic yards, and an average of 47 cubic yards every day, five days a week, 52 weeks per year.

The APC uses another method to calculate truck requirements for bottles and cans. It recommends using data they collected on average set-out volumes and set-out rates.[58] This method results in somewhat higher

[58] Ibid., Table VIII, p. 19.

capacity requirements but is perhaps more accurate since it is derived by measuring actual set-outs in the study areas.

The APC's data reflects an assumed set-out rate of 48% and 1,000 households per route. In Berkeley, an average of 7,000 households are served per day. With those assumptions, the APC's calculation can be applied to Berkeley with the following results:

Table 7: Average Daily Volume Capturable in Berkeley Using APC Assumptions

Material	Average Daily Volume	
	Cu. yds/route (1,000 households)	Cu. yds/ day (7,000 households)
Cans	4.6	32.2
Glass	5.6	39.2
Plastic	8.2	57.4
Total	**18.4**	**128.8**

Therefore, average daily volume can be estimated at 129 cubic yards per day for all container types, with plastic bottles accounting for 57.4 cubic yards per day.

The Ecology Center has five high-capacity trucks, each with a capacity of 30 – 35 cubic yards; two 1990 bin trucks at 17 cubic yards; and two older bin trucks for backup. The seven trucks in regular use have a combined capacity for glass and cans of just over 60 cubic yards. Thus, if each truck could make two full trips every day and every route were average, only a few yards of extra capacity would be required and could probably be accommodated with the backup trucks. This calculation also assumes that plastic could be collected commingled with both cans and glass. Commingling adds processing costs but avoids the additional costs associated with supplying and collecting an additional curbside tote box.

In Berkeley, demographics, terrain, and the existing refuse collection days require curbside recycling collection routes that vary widely from the statistical average. The routes with highest participation are often the least efficient to collect because they are far from the recycling yard, the stops are far apart, and narrow and dead-end streets require extra time for maneuvering. Therefore, it is not always possible to collect two full trucks in an eight-hour shift from routes on the eastern side of Berkeley.

Also, in high-participation areas, one route cannot serve a thousand houses per day, so more and smaller routes are necessary.

Replacing the two bin trucks with high-capacity trucks would add about 9 cubic yards for glass, cans, and plastics (increasing capacity to 70 cubic yards) without requiring additional staff. If the bin trucks were also used on heavy days, total capacity would be over 80 cubic yards for one trip, with an additional 40 – 50 cubic yards available for second trips and the remaining 30 – 40 cubic yards available for overtime collection on heavy days.

One option is to add plastic compactors to all seven trucks to increase collection capacity. The APC study did extensive testing of several different makes and models of on-board compactors. They increase loading time on the route but also increase collection capacity somewhat. Overall, however, the study found on-board compaction to be of marginal use in bottle-bill states using commingled collection. Adding compactors in the space behind the cab of the Lodal trucks (two bin trucks and three high-capacity trucks) and under the frame of the other two high-capacity trucks might provide necessary overflow capacity to prevent the container compartments from filling up before the paper sections. This installation would require the collectors to manually sort plastic at the curb, adding considerable time to the collection.

Also, all the compactors tested in the APC study had features that made them either inconvenient or difficult to load and unload. One of the test routes, in West Linn, Oregon, used a compactor for commingled cans and plastic. The test showed that there was no problem with interlocking the materials, which could be routinely processed at the sorting facility. The particular compactor tested in the study is too small to be of use on the Ecology Center's trucks, but the idea might be expanded into something useful locally. If a compactor could be fed from the overhead troughs and fitted to use the entire can compartment for storage of compacted cans and plastic, collection capacity would be added with very little increase in collection time.

Clearly, the alternatives for collection should be analyzed before investment is made in new equipment. However, a range of costs can be determined for the scenarios suggested above.

1. Overflow compactors for plastic only, 7 trucks	$ 70,000
2. Overflow (2) and commingled (5) compactors	95,000
3. One new collection truck	130,000
4. One new truck, commingled compactors 6 trucks	220,000

5. One new truck, commingled (6) and overflow (2) compactors 240,000
6. Two new collection trucks 260,000
7. Two new trucks, commingled compactors 7 trucks365,000
8. Two new trucks, commingled (7) and overflow (2) compactors 385,000

Additional routes would have to be added and more trips made, so there would be an increase in labor and operating expenses, such as fuel and maintenance. Test or pilot routes could be done in various areas of the City to provide data on participation, collection time, and volumes. These data could be used to predict closely the additional operating costs necessary to add plastic bottles to the curbside collection program. In the absence of real data, an example can be modeled on the APC study and knowledge of the local conditions and program.

We have calculated incremental operating costs for adding plastic bottles based on the following assumptions:

1. Three new routes are required, an increase of 10%.
2. All routes require two or three trips, for a total of 70 trips per week, an increase of 30%.
3. An average of 0.6 extra hours per route would needed to collect plastic; half of this increase can be accommodated in the regular shifts, and half results in overtime.

Those assumptions would add these approximate additional costs:

1. Three driver-days per week = .6 full-time equivalent driver $23,000
2. Thirty percent increase in fuel and maintenance costs 8,500
3. Overtime pay for 0.6 hours @ half of 33 routes /week @ 1.3 crew per route 14,270

Estimated Annual Incremental Operating Expenses $45,770

These figures are indicative but not complete. Other factors may increase or decrease incremental expenses. For example, adding a new truck would increase insurance expense, while replacing the bin trucks would eliminate the cost for forklift operation, fuel, and maintenance. A potential savings from re-routing might be used to offset some of the additional operating costs.

Projected revenues

Market prices for plastic bottles in 1996 have dropped dramatically from the high experienced during 1995. In California, however, PET prices are subsidized by the plastics industry and should therefore remain high as long as container redemption legislation is in effect. The following table indicates the revenue expected at today's market prices.

Table 8: Annual Revenue Expected from Sale of Collected PET and HDPE

Program	PET tons	Sales	PET crv*	HDPE tons	Sales	Total Tons	Total Sales
Dropoff	6	$4,620	$2,520	32	$4,480	38	$11,620
BuyBack	12	9,240				12	9,240
Curbside	23	17,710	7,820	110	15,400	133	40,930
Commercial	21	16,170	6,720	50	7,000	71	29,890
Totals:	62	$47,740	$17,060	192	$26,880	254	$91,680

*California redemption value; not included for BuyBack since it is paid to customers.

Summary of costs for adding plastic bottles to Berkeley recycling programs

Adding plastic bottles to the recycling system in Berkeley could be done through some or all of the existing programs. PET and HDPE are already accepted at the dropoffs, and the BuyBack began purchasing PET on April 2, 1996. The cost for these additions is expected to be covered by the revenue from sales. Advertising the program would boost tonnage.

Adding plastic bottles to the residential curbside and commercial collection programs would increase the tonnage collected, but at a net cost per ton. To make the addition, the sorting system must be expanded to process plastic commingled with other containers from either the curbside or commercial programs. So it would make economic sense to add plastics to both household and commercial programs if the expansion is done.

Table 9 shows the costs and revenues for adding plastic bottles to both the commercial and curbside programs. The table includes revenue from 71 tons from commercial collection and 133 from curbside collection. The costs include a good public education program and capital costs from scenario 5 above. The net incremental cost for this scenario is $826 per ton averaged over the first four years of the program.

If the other capital-cost scenarios are substituted in the table, a range of net costs may be obtained. The low end of the range would be $580 per ton for scenario #1 and the high would be $1,033 for scenario #8.

Table 9: Summary of Costs for Adding Plastic Bottles to Commercial and Curbside Collection in Berkeley

	1st Year	2nd Year	3rd Year	4th Year	Total
Processing Equipment	$64,100				$64,100
Commercial Collection Public education	10,000	10,000	10,000	10,000	40,000
0.5 FTE collector	27,710	27,710	27,710	27,710	110,840
Processing costs @ $250/ton	17,750	17,750	17,750	17,750	71,000
Curbside Collection					
Public education	40,000	20,000	20,000	20,000	100,000
One truck and compactors $240,000 loan with interest @ 40 months	84,444	84,444	84,444	28,148	281,480
Operating costs	45,700	45,770	45,770	45,770	183,080
Processing costs @ $200/ton	26,600	26,600	26,600	26,600	106,400
Total Incremental Costs	**$316,374**	**$232,274**	**$232,274**	**$175,978**	**$956,900**
Revenue					
Commercial	29,890	29,890	29,890	29,890	119,560
Curbside	40,930	40,930	40,930	40,930	163,720
Total Revenues	**$70,820**	**$70,820**	**$70,820**	**$70,820**	**$283,280**
Net Incremental Cost	**$245,554**	**$161,454**	**$161,454**	**$105,158**	**$673,620**
Net Cost per Ton	**$1,204**	**$791**	**$791**	**$515**	**$826**

Links between plastic reprocessing and landfilling

The calculations above assume that curbside collection would have no impact on plastic packaging use. However, it is likely that establishing plastics collection would increase consumption by making plastic appear more ecologically friendly both to consumers and retailers. By making plastics seem ecologically friendly, collecting plastics at curbside would legitimize the production and marketing of packaging made from virgin plastic. But much of this packaging is in fact unrecyclable, so the effect could be a net increase in the amount of plastic discarded, collected as garbage at City expense, and sent to the landfill.

This is our reasoning: curbside collection would divert only about 8.4% of the available discarded plastic from waste, so even a small increase in plastic packaging sales would increase the plastic landfilled. If consumption of plastic packaging (all resin types) increased by only 9.2%, the amount of discarded plastic going to landfill would increase the total weight of solid waste by 0.3%. This is about the same amount that would be saved by collecting plastics at the curb. Thus, if collecting plastics contributed to any increase more than 9.2% or more in plastic packaging consumption, initiating a curbside pickup program would actually lead to an increase in the amount of plastic sent to the landfill.

The degree of contamination affects the net cost of operation, because of the cost of sorting out unacceptable materials and landfilling the contaminants, and because any impossible-to-remove residual contamination lowers the value of the product. It is reasonable to expect costly rejection of entire loads if exacting specifications are not reached, as recyclers have experienced with other materials. In mixed-plastic collection schemes, the contamination problem is amplified.

Two basic strategies have emerged: one is to accept only certain types of plastic as indicated by the code number on the bottom of each container. While this approach lowers processing costs by providing some degree of separation at the source, the public must be educated and the curbside handlers must be trained. Truck drivers must invest considerable time in sorting at the curb and in providing educational feedback to the residents. The other strategy is to collect all types of plastic bottles and sort them at the processing location.

8. HOW SOME OTHER COMMUNITIES HAVE HANDLED PLASTICS

As we have seen in the previous section, even when we use figures from industry sources, we are still left with major questions unanswered.

Ideally, someday all discards will be reused or recycled and none will be wasted. But what should be done today necessarily comes down to how scarce resources and funds can be used most effectively.

Published studies and phone conversations with discard handlers in other communities can provide valuable perspective. What we find is wide variation in programs. Major variables include the type of sorting that occurs; the degree to which plastic container manufacturers participate; and how much plastic handling is integrated into the rest of the discard management system.

St. Paul, Minnesota

The Saint Paul Neighborhood Energy Consortium (NEC) studied whether to add plastic bottles to the City of Saint Paul's existing curbside recycling program.[59] They estimated that curbside collection of PET and HDPE (#1 and 2) could cost $334 per ton for labor and equipment. Sorting would add $110 per ton. Collecting only PET at curbside would cost between $245 and $325 per ton. These figures compare favorably with those from other midwestern and eastern cities, which ranged from $300 to $1400 per ton.[60]

In all the cases they studied, taxpayers pay the costs of collection and sorting. While PET and HDPE plastic bottles would have made up only about 3% of the recyclables collected, they would account for 12% of the collection budget. Based on their study, the NEC concluded that it would not be in the interest of the Saint Paul taxpayers or the city's natural environment to add plastics to the recycling program unless it were done through additional dropoff sites. They noted that the public was not asking for collection of plastics when the study was done in April 1994. Rather, a plastics industry organization had initiated the discussion. No other packaging industry had come forward to ask that their materials be added to the Saint Paul program.

The Saint Paul researchers concluded that while curbside collection of plastics might serve the interests of the plastics industry, it was not beneficial to the residents of Saint Paul and, in fact, could jeopardize the existing recycling program.

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[59] Saint Paul Neighborhood Energy Consortium, "Residential Collection of Plastics in Saint Paul: A Report on the Economics of Collection, End Markets, and Program Feasibility", April 1994.

[60] Chaz Miller, "HDPE: High-Density Polyethylene Bottles and Containers", *Waste Age*, August, 1995, p.85.

Philadelphia, Pennsylvania

The City of Philadelphia provides curbside recycling services to 560,000 households. Budgetary limitations forced the recycling office to stop collecting plastics. Plastics were dropped instead of other materials because of their low density. Plastic took up about 45% of the collection volume but contributed only 6% of the weight.[61]

El Cerrito, California

The City of El Cerrito picks up PET containers at curbside. The manager of the collection program estimates that 1/4 to 1/3 of all the plastics collected are incompatible or unrecyclable and must be sent to a landfill. Plastics collected at curbside are less contaminated than the plastics collected at the dropoff facility because the El Cerrito collection crews are trained to hand-sort the materials that residents set out, and they leave the unrecyclable plastics in the collection bins. The recycling program director indicated that a major problem is the confusion caused by the chasing arrows symbol, as discussed earlier. Since the symbol appears on so many things, it causes the public to think that all plastics are recyclable.[62]

Sonoma County, California

Sonoma County cut waste at its landfills by 39% from 1989 to 1995 despite rapid population growth. Little of this change had to do with increased curbside program participation. Instead, consumers purchased less and therefore threw away less disposable packaging. Shoppers who avoided elaborately wrapped goods not only reduced waste but sent a message to retailers that overpackaged goods were not acceptable.[63]

Germany

Germany's Green Dot program illustrates the “polluter pays” principle. The Green Dot program requires industries to take back, reuse, or recycle packaging materials including plastics. Companies that do so are permitted to display the ecomark Green Dot on their product.

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61 Personal correspondence with Tom Klein, City of Philadelphia Recycling Office, March 22, 1996.

62 Personal correspondence with the General Manager of the El Cerrito Recycling Center, El Cerrito, CA, January 6, 1995.

63 “Well on the Way to a Lofty Goal,” *The Sonoma County Press Democrat,* June 17, 1995.

The program was implemented by national ordinance in 1993, and by early 1994 several changes had occurred. Packaging consumption had been reduced by 4%; the proportion of beverages sold in refillable containers had increased; reusable and recyclable shipping containers had been developed; and many other product packages had been eliminated or were made easier to recycle. One of the provisions in the legislation was that stores were required to provide bins for customers to use for discarded packaging. This requirement led retailers to pressure suppliers to reduce these materials.

The German program is not without its problems. Since the main drive of the program was to preserve shrinking landfill capacity, closing the materials-flow loop was not imperative. As a result, Germany exports post-consumer plastic and other materials, some of which are highly contaminated.[64] Much of these exports go to Asia, where some is reclaimed and the rest is openly dumped. Also, the packaging industry was permitted to establish a separate, privately financed operation, called Duales System Deutschland (DSD) to collect and sort packaging materials. DSD has run out of capacity and is experiencing financial problems because of delinquent Green Dot payments from industry.[65] Problems with the program notwithstanding, transferring responsibility to product and packaging manufacturers has yielded positive results, most visibly in the reduced volume of packaging.

Taiwan

Taiwan instigated mandatory recycling of PET soft drink bottles because of shrinking landfill capacity. The country's twelve soft-drink manufacturers put out receptacles for the bottles, collect and sort them, and pay for baling. Baled plastic material is picked up and converted to reusable resin by a recycling corporation established by the country's two largest PET bottle makers.

The industries that participate are permitted to display an ecomark on their products. An important feature of the program is governmentally arranged education in the nation’s grade schools about the environmental benefits of purchasing ecomarked products. Similar systems are being set up for other products, including soy sauce containers.

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64 *Plastics Recycling Update, Resource Recycling,* publisher, v8, No.11, November 1995.

65 Bette K. Fishbein, *Germany, Garbage, and the Green Dot: Challenging the Throwaway Society,* Inform, 1994.

This is one program that facilitates primary, not secondary, recycling. Since the post-consumer material goes directly back to the manufacturers, there is a strong incentive to consider recyclability and source reduction as a part of product design. One problem with the program was that it initially required authoritarian government intervention to get it going, and that encountered strong resistance from businesses.[66] Nevertheless, by late 1995 more than 65% of Taiwan's PET bottles were being recycled.[67]

Some common elements

These examples teach us the following :

- Collecting discarded plastics at curbside and processing them is expensive and requires subsidies, usually from taxpayers.
- Increasing the collection of high-density non-plastic materials (paper, magazines, and yard debris) can be a more cost effective way to reduce the municipal solid waste stream than collecting plastics.
- A large percentage of the target plastic material will be missed by collection programs (even Taiwan's comprehensive PET reclamation program lets more than 30% of the targeted containers slip through to the landfill).
- Collected material includes a percentage of unusable contamination that must be landfilled.
- Recycling programs providing benefits such as closed-loop material flow and highest and best use of resources work best with full participation by the companies that make the material in the first place. Programs that make manufacturers take responsibility for the life of the materials they produce, as in Germany and Taiwan, have the best results.

9. SEVEN COMMON MISCONCEPTIONS ABOUT PLASTICS

This investigation into plastic packaging has revealed a great deal of information. Most plastic packaging is used only once, its chemical stability keeps it from degrading in the environment for many years, and it is accumulating in landfills. The processes that produce the plastics use

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[66] George C. Lodge and J.F. Rayport, "Knee-deep and Rising: America's Recycling Crisis," *Harvard Business Review,* Sept.-Oct. 1991, p.134.

[67] "Plastics Recycling Update," op.cit.

fossil resources, pollute the air and water, and consume large amounts of energy.

It seems clear that producing and using plastic as a packaging material, and taking market share from more recyclable and reusable packaging, is a bad idea from an environmental standpoint. So why is the plastic packaging business growing? One big reason is that popular misconceptions about plastic production and reprocessing contribute to the industry's growth. Some of them are presented here.

Misconception # 1: Plastics that go into a curbside recycling bin get recycled.

Not necessarily. Many plastics are unrecyclable, and the recyclable ones must be separated out. The rest go to waste.

Collecting plastic packaging at curbside fosters the belief that, like aluminum and glass, the recovered material is converted into new packaging. In fact, most recovered plastic packaging is not made into packaging again but into new secondary products such as textiles, parking lot bumpers, or plastic lumber – all unrecyclable products. This does not reduce the use of virgin materials in plastic packaging.

One of the goals of the Council for Solid Waste Solutions, an industry association formed by major resin producing companies, is to increase curbside pickup of plastics. The Council's "Blueprint for Plastic Recycling" is aimed squarely at convincing the 6,000 or so municipalities around the country that already have curbside recycling service to add plastics.[68] How this material is to be handled after being picked up is not addressed in the blueprint, however. In many cases, communities have adopted collection programs only to find that there is no reasonable market for the material, or that they must incur additional costs to clean and separate it to market specifications. **"Recycled" in these cases merely means "collected," not reprocessed or converted into useful products.**

Misconception # 2: Curbside collection will reduce the amount of plastic landfilled.

Not necessarily. If establishing collection makes plastic packages seem more environmentally friendly, people may feel comfortable buying more. Curbside plastic collection programs, intended to reduce municipal

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68 *Recycling Today*, May 1991, p.60.

plastic waste, might backfire if total use rises faster than collection. Since only a fraction of certain types of plastic could realistically be captured by a curbside program, the net impact of initiating curbside collection could be an increase in the amount of plastic landfilled.

Furthermore, since most plastic reprocessing leads to secondary products that are not themselves recycled, this material is only temporarily diverted from landfills.

Misconception # 3: A chasing arrows symbol means a plastic container is recyclable.

The arrows are meaningless.

Every plastic container is marked with the chasing arrows symbol. A survey of 804 people in Saint Paul, Minnesota, revealed that 7 out of 10 people believed the symbol means "recyclable."[69] Many even believe the symbol indicates the container is composed of recycled material. Actually, the only information in the symbol is the number inside the arrows, which indicates the general class of resin used to make the container.

The plastics industry adopted this symbol in 1988 to identify the resins when state legislatures were discussing bans on plastic containers. But the plastics industry says it never intended the chasing arrows to indicate recyclability or identify recycled content, but only to be a catchy graphic to point out the number inside that identifies the type of resin.[70] The symbol is misleading; nevertheless, the plastics industry has resisted consumers' efforts to modify it.[71]

The attorneys general of 11 states also objected to false and misleading claims about plastic recyclability. The recent settlement that they reached with the American Plastics Council paves the way for a first-ever definition of what claims can or cannot be made about plastic recycling and recyclability.[72]

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[69] Saint Paul Neighborhood Energy Consortium, op.cit.

[70] *SPI Resin Identification Code: A White Paper to Evaluate Options To Improve the Code's Effectiveness,* a joint publication of the National Recycling Coalition and The Society of the Plastics Industry, July 28, 1993.

[71] V. Wigotsky, "To Market To Market," *Plastics Engineering*, June 1995, p.16.

[72] Tom Ford and Roger King, "APC Accord Limits Recycling Claims," *Waste News*, January 8, 1996, p.12.

Misconception # 4: Packaging resins are made from petroleum refineries' waste.

Plastic resins are made from non-renewable natural resources that could be used for a variety of other applications or conserved.

Some people believe that the raw materials for packaging plastics come from an otherwise useless industrial waste stream. They believe that if these plastics were not made, the raw materials would be dumped into the environment as a hazardous waste. But actually, most packaging plastics are made from the same natural gas used in homes to heat water and cook.

Misconception # 5: Plastics recyclers pay to promote plastics' recyclability.

No; virgin resin producers pay for the bulk of these ads.

Billboards that claim plastic is recyclable and beseech consumers to get involved imply that plastic recycling is an established industry impatiently awaiting consumer participation. In fact, most such ads are placed by virgin plastic manufacturers whose goal is to promote plastic sales. These advertisements are aimed at removing or diminishing virgin plastic's greatest challenge to market expansion: negative public conception of plastic as unrecyclable, environmentally harmful, and a major component of wastes that must be landfilled or burned.

Misconception # 6: Using plastic containers conserves energy.

When the equation includes the energy used to synthesize the plastic resin, making plastic containers uses as much energy as making glass containers from virgin materials, and much more than making glass containers from recycled materials. Using refillables is most energy conservative.

Energy use studies that compare various packaging materials often do not account for the large amount of energy required to synthesize plastic resin. Most of the energy and environmental costs of plastics are hidden because they are incurred in the plastic factory. Also, life-cycle assessments often assume containers will be used only once. The practices of refilling and reuse, especially if carried out on the local level, have the greatest potential for reducing energy consumption no matter what material is used to make the containers.

Misconception # 7: Our choice is limited to recycling or wasting.

Source reduction is preferable for many types of plastic and isn't difficult. Opportunities include using refillable containers, buying in bulk, buying things that don't need much packaging, and buying things in recyclable and recycled packages.

Many people take plastic packaging as a given and narrow the issue down to the simple question of how best to dispose of it. In the resulting turmoil, obvious alternatives may be overlooked, such as reducing or eliminating our consumption of plastic packaging. Simple, effective source-reduction strategies for individuals and households are: a) using refillable containers; b) buying in bulk; c) selecting products that use little or no packaging, and d) choosing packaging materials that can be recycled and are made from recycled materials such as glass, metal, and paper. Holding companies accountable for the material they sell by legislatively demanding recycled content also has been shown to work on the city, state, and national levels.

Why are there so many misconceptions? The use of plastic as a packaging material is on the rise. Since so many products are available in plastic packaging, the choice of plastic is a matter of convenience. The desire for convenience coupled with a throwaway mentality or culture supports the flow of disposable plastic packaging. Yet people are concerned about the accumulation of discarded plastic in landfills and in the environment; they show this by participating at a high level in curbside collection programs and voting for mandatory container deposits. The conflict of interest between the convenience of throwaway containers and responsibility for long-lasting waste and environmental damage has shifted public hope and attention to plastic recycling.

The popular ideal appears to be for some sort of technological breakthrough to make using plastic acceptable without requiring any change in consumption or discard practices. The plastics industry has responded by advertising plastic recyclability and joining the chorus of technological optimism while continuing to promote the consumption of single-use plastics.

10. ALTERNATIVES

How can we address the problems posed by plastic packaging in a constructive way? There are five main actions the public can take.

Reduce the use – source reduction.

The most direct way to eliminate the problems that stem from producing, using, and disposing of plastic packaging is to reduce the use of packaging. Retailers and consumers can select products that use little or no packaging, and when packaging is necessary, select packaging materials that are recycled into new packaging — such as glass, aluminum, and paper. Many product manufacturers, such as water bottlers, have only recently switched from an easily recyclable container to plastic. If people refuse plastic as a packaging material, the industry will decrease production for that purpose, and the associated problems such as energy use, pollution, and adverse health effects will diminish. Established waste management groups cannot be expected to organize or support source reduction efforts. For example, the primary plastic recycling entity, the American Plastics Council, does not include source reduction in its charter and systematically overlooked it[73] until recently, when it began promoting lighter-weight packages as source reduction.[74] This "solution" creates the same high number of containers and tends to legitimize their production. Reducing the use lies in the hands of consumers, retailers, and elected officials.

Reuse containers.

One effective and inexpensive source-reduction technique is container reuse. Since refillable plastic containers can be reused about 25 times, container reuse can lead to a substantial reduction in the demand for disposable plastic. The direct result is reduced use of materials and energy, with the consequent reduced environmental impacts. In addition, some important indirect benefits stem from container reuse. If reuse becomes a market objective, resin and container designers will take into account the fate of the container beyond the point of sale and consider the service the container provides. "Design for service" differs sharply from the "design for disposal" paradigm underlying most plastic packaging today. As with take-back programs, reuse makes new demands on both the material and the infrastructure. Container makers can directly participate in developing a refilling infrastructure and encouraging public participation. An innovative approach to encourage consumers to choose reusable and refillable containers could be to include these containers in curbside collection services. The benefit of such an approach or any public education program that promotes reuse

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73 "Management of Plastic Wastes in the ECE Region," United Nations Publication E.93.II.E.3, New York, N.Y., 1992, p.44.

74 American Plastics Council full-page advertisement in the *Atlantic Monthly,* April 1996, for packages that are lighter now compared to 20 years ago.

would be a higher level of public awareness about how their choices in consumption affect the environment.

Require producers to take back resins.

Getting plastic manufacturers directly involved with plastic disposal and waste closes the materials loop, which can lead to developing more recyclable materials and establishing an infrastructure to accomplish the reprocessing. Closing the loop stimulates designers and manufacturers to consider the product's life cycle from cradle to grave.

Container makers can make reprocessing easier by limiting the number of container types and shapes, using only one type of resin in each container, making collapsible containers, using water-dispersible adhesives for labels, and phasing out associated metals such as aluminum seals.[75] Resin manufacturers can limit the variety of resins within each resin type, avoid using pigments, and formulate resins to better withstand post-consumer processing. Both container and resin makers can help develop the reprocessing infrastructure by taking back plastic from consumers.

Legislatively require recycled content.

Requiring that all containers sold contain a percentage of post-consumer material reduces the amount of virgin material consumed. Although not as effective as other source reduction techniques, mandating recycled content is one way to implement primary recycling and, as a result, to close part of the materials-flow loop. Worn-out refillable containers could become a source of feedstock. Incorporating primary recycling into a system of container reuse would be straightforward, since established transportation lines exist between container makers and filling locations.

If container makers were required to use recycled material, designers would be stimulated to create containers that are more recyclable. If resin producers participated in post-consumer plastic processing, polymer materials would be altered to be more recyclable. In these ways, instituting recycled-content practices would lead to life-cycle consideration during design and manufacturing.

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75 Peter Anderson, op.cit., p.65.

Standardize labeling and inform the public.

No matter what kind of program is adopted for dealing with plastics, standardized terms and labels are necessary for the sake of clarity and fairness. The chasing arrows symbol is an example of an ambiguous and misleading label. Significantly different standardized labels for “recycled,” “recyclable,” and “made of plastic type x” must be developed.

In addition, if a working definition can be found for “ecologically friendly,” an ecomark system similar to those in Taiwan and Germany could be initiated to distinguish products that conform to the definition from those that do not. An independent entity could be used to audit the environmental impact of products and certify conformance. The implementation of standards and labeling programs must be accompanied by public education.

The goal of both standardized labeling and public education is to open access to, and activate public participation in, plastic packaging practices, programs, and policies.

11. CONCLUSIONS

1. Plastic packaging offers advantages such as flexibility and light weight, but it creates problems including consumption of fossil resources, pollution, and high energy use in manufacturing; accumulation of wasted plastic in the environment; migration of polymers and additives into foods; and an abundance of public misinformation about plastics issues.

2. Curbside collection of discarded plastics is expensive and has limited benefits in reducing environmental impacts, diverting resources from waste, or achieving mandated recycling goals. Residential curbside collection in Berkeley would capture only about 132 tons a year - less than one-half of one percent of municipal discards.

3. It is likely that establishing plastics collection would increase consumption by making plastic appear more ecologically friendly both to consumers and retailers. By making plastics seem ecologically friendly, collecting plastics at curbside would legitimize the production and marketing of packaging made from virgin plastic. But much of this packaging is in fact unrecyclable, so the effect could be a net increase in the amount of plastic discarded, collected as garbage at City expense, and sent to the landfill

4. Increasing the capture rates of aluminum, glass, paper, or yard debris in Berkeley could divert more resources from landfills than collecting plastics at curbside, since plastics are a small fraction of the waste stream's weight.

5. Existing plastic recycling practices have significant hidden problems, including the creation of unrecyclable products.

6. The question of whether to recycle plastics or not should be replaced by the question "How can we best reduce the environmental impact of packaging?"

7. Strategies that reduce the environmental impact of plastics and lead to systematic improvements in consumption and disposal practices are to:
   - Reduce the use – source reduction;
   - Reuse containers;
   - Require producers to take back resins;
   - Legislatively require recycled content;
   - Standardize labeling, and
   - Inform the public.