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Evaluation of Plastics Recycling Systems

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EVALUATION OF PLASTICS RECYCLING SYSTEMS

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EXECUTIVE SUMMARY

Evidence has emerged that plastic debris in the marine environment is a serious problem for a number of species and for community and user groups that depend upon the marine environment. Since plastic articles are relatively strong and decay resistant, they accumulate in the marine environment. Several common varieties of plastic float at the ocean surface, the most biologically productive zone of the water column, and pose a potential hazard to marine life through entanglement and ingestion. Evidence collected over the last 15 years indicates that the plastic hazard to marine life is not limited to a few molded shapes or polymer types. A variety of shapes including plastic bags, sheeting, 6-pack retainer rings, nets, fishing line, synthetic ropes, flotation blocks, cups, strapping bands, and plastic pellets have been associated with marine life mortality. The constituent polymers of the articles include polyethylene, polypropylene, polyester, polystyrene, and nylon.

These plastics enter marine waters from a variety of sources including beach litter, sewage outfalls, and ocean-going vessels. The amounts of plastic entering the marine environment from each of the various sources is unknown, however, the largest source is generally thought to be overboard discharge of solid waste from various types of vessels.

RECYCLING TECHNIQUES

Recycling is often thought to be an attractive means of curbing the flow of plastic residues into the marine environment. In principle, all of the polymer types listed above are recyclable and, if collected, could be reprocessed into useful products. Several reclamation techniques exist for plastics. The processes differ fundamentally in the types of feedstocks that are permissible and the types of resulting products. The available processes are as follows:

	Process	Permissible Feedstock	Products
1)	extrusion	mono or mixed polymers	plastic articles
2)	depolymerization	monopolymers	monomers, oligomers
3)	pyrolysis	mono or mixed polymers	liquid and gaseous fuels
4)	incineration	mono or mixed polymers	thermal or electrical power

Extrusion

Extrusion is the process of mixing and heating thermoplastic material and extruding it directly into new objects or into plastic pellets which

are then used as a feedstock to manufacture new plastic articles. Extrusion is the process most often used to reclaim waste plastics. Equipment has been developed for the reprocessing of monopolymer plastic waste and mixed polymer waste via extrusion.

The most important disadvantage of reprocessing by extrusion is that reactions take place which degrade the properties of the reclaimed polymers. The amount of degradation varies for the different polymers and depends somewhat on process details. Techniques exist for reducing property degradation, mostly through inclusion of additives or blending with virgin polymers. However, extrusion-induced property degradation is inevitable. Without expensive upgrading, extruded waste plastics can only be used for less demanding applications than the virgin polymers.

Since plastic is produced in a wide variety of polymer types, waste plastic discarded by consumers (referred to as "post-consumer plastic"), the largest source of waste plastic, is generally a mixture of polymers. Typically, waste plastic is also mixed with other components of the waste stream. In a few areas, however, waste plastic is being collected separately from other wastes. Specialized extrusion devices have been developed to enable source-separated mixed polymer waste plastic to be extruded into useful articles. Property degradation of mixed polymer feedstocks is even more severe than that for most monopolymers because the various polymers are generally incompatible with each other and the resulting bond between polymers is poor. In order to produce useful products from the extrusion of mixed polymer feedstocks, composition is controlled so that one dominant polymer can flow and engulf the other incompatible polymers. Unfortunately, the products of mixed polymer extrusion are limited to articles having a relatively large cross-section and can compete with only very low quality plastic. To date, the products of mixed polymer extrusion have been used primarily as a rot-resistant substitute for treated lumber. Therefore, the reprocessing of mixed polymer waste by extrusion has done little to displace the use of virgin polymers.

Depolymerization

Depolymerization is a chemical process in which plastic is decomposed into its constituent monomers or oligomers. These compounds can be used to regenerate the polymers. An important advantage of the monomer recovery process is that waste plastics can be used to produce high-grade virgin polymers. Unfortunately, current monomer recovery processes require a clean monopolymer feedstock. Unique reactors are required for each polymer. For this reason, monomer recovery has only been applied to the recycling of certain easily collectable monopolymer wastes from manufacturing processes. Considering the cost of separating mixed polymer waste streams, such as those from municipal sources, monomer recovery currently is not economically attractive.

Pyrolysis and Incineration

Pyrolysis is a thermo-chemical process in which plastic can be decomposed into simpler compounds. The process is in some cases similar to that of monomer recovery; however, the process is tolerant of mixed

polymer feedstocks. The chemical products of pyrolyzing mixed waste plastic are themselves a chemical mixture. Typically, the pyrolysis processes are adjusted to produce a useful mixture of liquid or gaseous hydrocarbons which are useful as fuels or as chemical feedstocks.

Incineration is a process similar to pyrolysis in that the products of the process are ultimately energy, not plastic. As a result, resource recovery via both pyrolysis and incineration are not generally considered to be recycling.

Economics of Plastic Recycling

Most of the worldwide plastic recycling activity is centered around the reprocessing of a single polymer variety, polyethylene teraphthalate (PET). PET is commonly used in the production of plastic beverage bottles and is collected as a result of beverage bottle deposit legislation enacted in parts of the U.S., Canada and Europe. With the exception of PET, very little post-consumer plastic is being recycled, in either monopolymer or mixed polymer form.

The reason for plastic's low recycling rate is that under the current economic structure in the industrialized world, the costs of collecting and reprocessing plastic generally exceed the revenue potential of the reclaimed material. Since plastic recycled via extrusion is a downgraded substitute for virgin plastic or a substitute for other materials, such as lumber, potential revenues from the sale of reclaimed plastic are limited by the current prices of virgin materials. With the current revenue potential of reclaimed plastic and the costs involved with grinding, cleaning and extruding waste plastic, plastic reprocessors can only offer collectors of waste plastic a small price, if any, for their waste plastic feedstock. The current prices paid for bales of the most commonly reprocessed monopolymer plastics (PET and high-density polyethylene) are generally in the range of $0.05 to $0.10 per lb, depending primarily on the level of contamination. The prices paid for mixed plastics are generally even lower, ranging from zero to $0.05 per lb.

With these prices, there is little incentive to establish collection channels for post-consumer plastic. In contrast, the majority of waste plastic resulting from the manufacturing process is being reprocessed because of the relative ease of capture (low cost) and the fact that most waste plastic from manufacturing can be collected in a monopolymer form with very little contamination. For the case of waste from manufacturing, in general, reprocessing is economical because the cost of collection is relatively low.

Where consumer plastic is being collected in the industrialized world, institutional incentives are generally involved. Common methods of stimulating plastic recycling are container deposit laws and curbside collection programs.

Another contrasting economic situation exists in the developing world where, in many places, post-consumer waste plastic is commonly collected and reprocessed. Again, relatively low collection costs made possible by low labor costs enable economical plastic reprocessing.

Despite the relatively high cost of collecting and reprocessing plastics, there is a considerable amount of interest in the recycling of plastics, motivated primarily by a desire to reduce the amount of material that must be landfilled or incinerated. In the U.S., a substantial amount of legislation has been enacted or is being considered, mostly at the state level, which would affect the recycling of plastics. The legislation falls into the following three catagories:

1) regulations to reduce the amount of waste generated;

2) techniques to increase the diversion of wastes into recycling channels; and

3) techniques to increase the demand for recycled materials.

Legislation or local regulations have been responsible, in part, for most of the plastic recycling activity in the U.S., either through container deposit laws, curbside collection programs, or grants to reprocessors.

Recycling Plastics from Ocean Vessels

For vessels plying international waters, the most commonly used method of solid waste disposal has been overboard discharge. However, beginning in 1989, overboard disposal of plastics will be prohibited for most of the world's fleet by the recently ratified Annex V of the 1973 International Convention for the Prevention of Pollution from Ships (MARPOL). As a result, the practical options for disposing of plastic waste that is generated aboard ships include incineration and on-shore recycling or disposal.

Waste plastic from ships could potentially be recycled if it is source separated from other wastes and delivered into on-shore recycling channels. One significant obstacle to the recycling of waste plastics from ships is the U.S. Department of Agriculture's requirement for treatment of solid waste from foreign sources. Plastics and any other solid waste that has contacted certain foodstuffs or has been mixed with waste that includes food waste from foreign sources, must be disposed of through incineration, landfilling, or pulping into sewers. Even if waste plastics are cleaned and separated at the source from other wastes, plastics from vessels plying international routes used to package or contain certain foodstuffs are effectively excluded from recycling. Most other countries have similar regulations. As a result, under the present regulatory environment, only a portion of the plastics generated on-board much of the world's fleet is legally eligible for recycling.

Section 1

INTRODUCTION

Plastics, due to their physicochemical properties, have displaced substantial quantities of metals, wood, and natural fibers in both products and packaging. This situation has led to a projected increase in the use of plastics from about 6 billion pounds in 1960 to more than 50 billion pounds per year in the 1980s [1,2].

The same characteristics that make plastics versatile and durable also constitute serious problems in the identification, design, and implementation of suitable methods for their treatment and disposal. It has been estimated that the amount of post-consumer wastes generated in the U.S. in the 1980s will vary between 120 and 160 million tons/year [2,3]. Waste characterization studies of post-consumer wastes have shown that the concentration of total plastics in the waste stream has increased from about 2% to 3% by weight in the early 1970s to approximately 5% to 8% in the early 1980s [4,5]. Most recent analyses have demonstrated that the concentration of plastics in the waste stream varies from 9% to 11% in some areas of the country [6]. Approximately 80% of the discarded plastic is in the form of packaging, and the remaining 20% is durable plastic goods. The expansion in the concentration of plastics in the waste may be attributed to the increase in the use of disposable plastic materials. Thus, based on the concentrations determined recently, it can be estimated that from 6 to 12.8 million tons of plastics are discarded each year.

A certain amount of the plastic wastes find their way into the marine environment through a variety of means. These wastes have been identified as becoming causative agents of mortality of marine wildlife, primarily as a consequence of ingestion and entanglement. A wide range of sources contributes to the plastics pollution problem and definitive information regarding the total generation rates of plastic debris is lacking. Ocean-going vessels routinely discharge domestic waste overboard, and other major sources of plastic debris include fishing- and cargo-associated plastics. Attempts to quantify waste generation rates have extrapolated from point sources or have neglected large contributors and may therefore under-represent the magnitude of the plastic pollution problem. These pollutants may cause the accidental deaths of more than 1,000,000 seabirds and 100,000 marine mammals each year. This situation has been particularly noticeable in the Gulf of Mexico, where local governments in the State of Texas spend on the order of $14 million each year to clean up debris from the beaches [7]. On the other hand, the recovery and reuse of these materials could result in substantial contributions to litter reduction and to current energy conservation efforts.

An attractive means of curbing the occurrence of plastic residues in the environment is reuse through collection and reprocessing into useful products. Recyclable waste plastics can be classified into two categories according to source: pre-consumer and post-consumer plastics. Pre-consumer plastics include home scrap and off-specification virgin resins generated by producers of primary polymers and manufacturers of plastic products; and secondary waste plastic, which includes surplus or obsolete product inventories and contaminated manufacturing scrap. The greater part of the pre-consumer waste is collected and reused as feedstock in the manufacturing process and, consequently, only a small fraction reaches the waste stream. The packaging industry, on the other hand, generates large amounts of waste plastics. Unfortunately, the efficient reuse of post-consumer plastics is impeded by the fact that they include items that usually contain a certain amount of impurities.

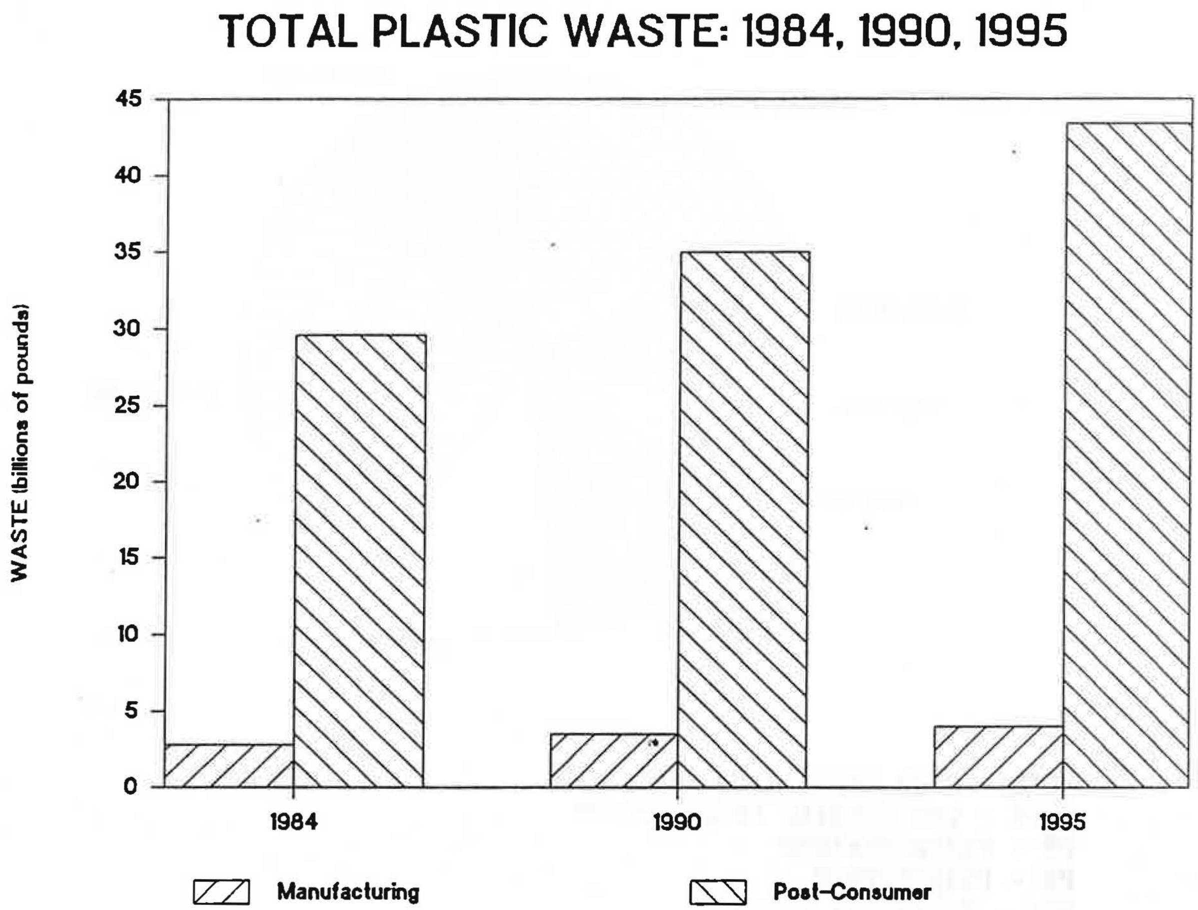
Judging from various surveys, overall, from 75% to 95% of pre-consumer waste plastics are recycled. On the other hand, the rate of recycling for post-consumer waste plastics in the U.S. is about 1%. The latter rate is low when compared to the average rate of 7% for post-consumer glass and 30% for aluminum [3]. Of the recycled post-consumer plastic, polyethylene teraphthalate (PET) is the predominant type of polymer. In the U.S., approximately 20% of post-consumer PET is recycled, or nearly 150 million pounds annually [3]. High-density polyethylene (HDPE) follows as the second most recycled post-consumer plastic. Figure 1 illustrates the estimated and projected quantities of pre- and post-consumer plastic waste, and Figure 2 presents a projection of the polymer distribution in the post-consumer waste stream for 1990 [8].

Plastics can be separated from the waste stream by way of two major approaches. The first involves source separation, and the second deals with recovery from mixed urban waste. Source separation of plastic waste is currently practiced to a limited degree by a small number of community-level recycling programs in the U.S., Canada, and Europe. Several techniques exist for converting source-separated mixed or mono-polymer waste plastic into useful products. PET carbonated beverage containers have been widely source-separated due to the impetus provided by bottle bill legislation.

Research work on the mechanical processing of the waste stream has demonstrated that plastics can be concentrated and, in some cases, separated from other fractions. However, the plastic fraction typically is composed of a variety of types of plastics, and it continues to have a certain amount of contaminants. The processing expense and lack of value for contaminated mixed plastics has prevented the practical development of mechanical plastics-separation facilities that use municipal solid waste as a feedstock.

The primary objective of the work described in the sections that follow is to assess the feasibility of recycling systems in reducing the flow of plastic refuse into the marine environment. In addition, the study presents and evaluates technical, economic and regulatory factors of major importance in the recycling system's success or failure.

Figure 1.

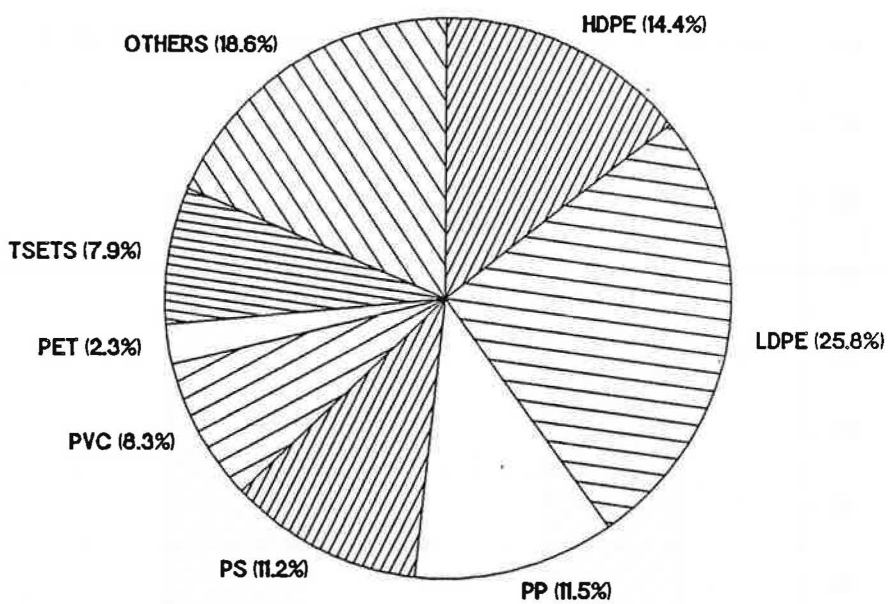


Source: Curlee (1986)

Figure 2.

PROJECTED POST CONSUMER PLASTIC WASTES

1990



Key:

HDPE - High Density Polyethylene
LDPE - Low Density Polyethylene
PP - Polypropylene
PS - Polystyrene
PVC - Polyvinyl Chloride
PET - Polyethylene Terephthalate
TSETS - Thermosetting Resins
OTHERS - Other Thermoplastic Resins

Source: Curlee (1986)

Section 2

CHARACTERISTICS OF PLASTICS

PLASTICS HAZARDOUS TO MARINE LIFE

Plastic debris in the ocean presents a hazard to marine life on a broad range of fronts. The known forms of the hazard have been summarized recently by the Center for Environmental Education [9], Weisskopf [10], and others. Visibly, the entanglement of large, surface-dwelling animals in lost or discarded plastic debris has received attention, but less visible effects such as ingestion, "ghost fishing", and ecological impacts also threaten the balance of the marine ecosystem. The plastic items that most commonly entangle marine animals are fishing nets, cargo strapping bands, and 6-pack container rings. Commonly ingested plastics include bags and sheeting, fragments, and raw plastic pellets. "Ghost fishing" is a term applied to submerged gill nets, lost crustacean traps, and other lost or discarded fishing gear that continue to trap and kill animals in the absence of active harvesting. Ecological impacts remain greatly undocumented, but predator/prey relations and food web flows could be affected by the plastic pollution problem, as well as creating the possibility of extinction. A list of plastic items associated with marine life mortality is presented in Table 1, and other plastic items commonly discarded in marine waters but not documented as having caused wildlife mortality are listed in Table 2.

Several intrinsic properties of plastic fishing nets, which make them desirable as fish catching devices are, not surprisingly, the same qualities that lead to marine animal entanglement. Firstly, nets made of polyethylene or polypropylene yarn (most trawl nets) float and therefore remain in the uppermost, highly biologically productive zone of the water column. This zone serves as the habitat for air breathing animals such as pinnipeds and sea turtles. The mesh size of a given fishing net generally determines which animals will become entangled, e.g., small-headed seals become stuck in nets with a mesh size similar to their head and appendage size. Since a range of mesh sizes exists among the lost fishing nets, few pinnipeds and sea turtles will be immune to potential entanglement. Even whales have been victims of net entanglement. The fibers of fishing nets are relatively strong and resist struggling, especially when the animal exerts force against several strands at once. Moreover, plastic fibers are highly decay resistant and remain sufficiently strong to pose an entanglement hazard long beyond the useful life of a fishing net. Another factor contributing to the high rate of animal entanglement is the fact that many nets are designed to be "invisible" in water. Fish become trapped in the derelict nets and serve as bait, which then attracts predators such as pinnipeds, sea turtles and sea birds, all of which can also become entangled.

The plastic strapping bands that bind small boxes, 6-pack container rings, and other plastic rings have entanglement potential similar to that

TABLE 1. PLASTIC ARTICLES DOCUMENTED AS HAVING BEEN ASSOCIATED WITH MARINE LIFE MORTALITY

Articles	Polymers
6-pack retainer rings	Low Density Polyethylene (LDPE)
Plastic bags	LDPE
Plastic sheeting	LDPE
Trawl nets	Polyethylene, Polypropylene, Nylon
Gill nets	Nylon, Nylon blends
Crustacean traps	Nylon
Fishing line	Nylon 6, Nylon blends, Nylon/Polyester composite
Rope - all synthetics	Nylon, Polypropylene, Polyester
Polystyrene cups, flotation blocks	Polystyrene
Strapping bands used to secure crates	Polyester
Raw plastic pellets, fragments	All types

TABLE 2. OTHER ARTICLES OF PLASTIC LITTER COMMONLY FOUND IN THE MARINE ENVIRONMENT WHICH ARE NOT DIRECTLY ASSOCIATED WITH MARINE LIFE MORTALITY

Articles	Polymers
Plastic barrels and buckets	HDPE
Plastic beverage containers	HDPE and PET
Other plastic bottles	HDPE and PET
Caps, lids, cups, utensils	All types

of fishing nets in that many of the common polymer formulations float in the habitat of pinnipeds and sea birds. These items also have band or ring diameters that could encircle the necks of these animals, and are strong and decay resistant. These objects are of sufficient numbers to present a threat to marine life even if the incidence of entanglement for any given object is low. The strapping bands and 6-pack rings can be particularly dangerous to seals because the animal can grow into its plastic "collar", restricting normal feeding and leading to neck wounds. Long, flexible objects such as rope, fishing line, and long strapping bands also pose an entanglement hazard because, due to the turbulent nature of ocean waters, these objects can become knotted and tangled themselves. Birds, especially pelicans, have become entangled in discarded fishing line.

Ingested plastic is known to cause mortality among several species of marine organisms and birds. Although evidence remains spotty and anecdotal, enough information exists to indicate significant numbers of marine animals are threatened by ingestion of plastic debris. Several physical properties of plastic contribute to its frequency of ingestion. As mentioned, many plastic items (polyolefins) float in the water column zone of richest biological productivity and therefore occur intermingled with the ocean's legitimate food sources. Secondly, plastic has an inert smooth surface and tends to become encrusted with epipelagic (lives on a floating surface) organisms, giving the plastic debris an exterior facade of authentic food items. Additionally, plastic's inert quality possibly leads the animal not to reject the food item based on a highly objectionable "flavor" such as usually occurs with toxic organic material. Finally, some plastic items could resemble the animal's natural food sources, such as plastic bags resembling jellyfish to sea turtles and raw plastic pellets and weathered fragments resembling fish eggs to sea birds. Potentially lethal problems due to plastic ingestion among all animals include choking, false satiation leading to malnutrition, intestinal blockage, ulceration, and possible absorption of PCBs.

"Ghost fishing" and unobserved animal/plastic interactions are primarily due to submerged gill nets and crustacean traps. Most gill nets are made of polyamide (nylon), which has a higher density than water and therefore sinks. These nylon nets can remain intact on or near the ocean floor and trap bottom dwelling organisms continually. Nylon gill nets generally have a short useful lifetime (1-3 yrs) after which they are discarded and replaced. Since the nets sink, they rarely are reported as beach or floating debris. Only those nets with corks or buoys still attached have been reported as floating net debris. These sea floor gill nets have an especially long lifetime since the first few meters of seawater absorbs the photodegrading UVb solar radiation. The magnitude of the ghost fishing problem may have been underestimated due to sinking, the high rate of gill net turnover, and protection from photodegradation. An experimental study of lost floating gill nets was conducted by the National Marine Fisheries Service in Hawaii. Preliminary findings indicate that the fishing ability of a derelict gill net depends on its age and configuration in the water. Drift patterns were found to depend on the ocean's surface circulation rather than the wind or deeper water currents [11]. Plastic crab pots and lobster traps can also continue to trap these crustaceans and fish after becoming lost. These traps are built to resist decomposition and, when lost, lie out of range of photodegradation, therefore having a long "ghost fishing" lifetime.

Research into the development of degradable plastics has indicated that currently available technologies for rendering plastics photodegradable could be utilized to reduce the hazard posed by some of the disposable items made of polyethylene and polypropylene. Rendering netting materials susceptible to photo- or biodegradation would also reduce the hazards posed by these materials. Preliminary evidence indicates that controlled degradation of netting materials may be feasible; however, more research is needed to develop the techniques for controlling degradation [12].

CONSTITUTIVE FACTORS AFFECTING THE RECYCLING OF PLASTICS

Once collected, waste plastics can be converted to numerous useful products via several alternative processes. In very general terms, the products and processes include: 1) for many plastics, reprocessing by extrusion and remolding into new plastic products; 2) conversion to monomers by thermal or chemical processes; 3) conversion to a range of simpler hydrocarbon compounds through pyrolysis; and 4) extraction of energy through incineration.

In order to reduce waste and raw material costs, virgin polymer producers and plastic product manufacturers commonly recycle sprues, trimmings and other pre-consumer scrap plastics resulting from the manufacturing process. Nearly all of this clean, segregated material is efficiently recovered. However, economical reprocessing of post-consumer waste plastic has proven to be difficult for several reasons. One technical factor is that, because of constituent chemistry, some varieties of plastics can be reprocessed and others cannot. This distinction defines the two main groups into which plastics may be divided: thermoplastics and thermosetting resins. Thermoplastics soften when heated, and so may be molded and cooled to obtain a desired shape. In principle, this process may be repeated either by direct reheating of scrap products or, preferably, after being size-reduced by grinding. Thermosetting plastics are cross-linked during their original processing and, unlike thermoplastics, cannot be softened by heating and processed again. Fortunately, thermoplastics make up the vast majority of post-consumer plastic waste. All of the plastics listed in Tables 1 and 2 are thermoplastics and are, in principle, reprocessible.

A second technical factor limiting the reprocessing of mixed plastics (thermoplastics) is polymer-polymer incompatibility. Most polymers are incompatible with other polymers for thermodynamic reasons. In general, blends of polymers do not mix and often phase separate into regimes dominated by one or another component. Moreover, the bonding (i.e., ability to transmit tensile and shear stresses) between regimes dominated by different polymers is typically poor.

Polymer-polymer incompatibility is further complicated by the fact that the various polymers can have different melting or softening temperatures. Blends of thermoplastic polymers can be heated to a point at which one polymer is soft and able to flow while another is still rigid.

Elevating the temperature of a blend so that all polymers are softened may be sufficient to cause chemical degradation of polymers having lower softening temperatures.

PROCESSING TECHNIQUES

The range of processing technologies available to convert waste plastic into useful products depends on the quality of the waste, the degree of chemical damage (aging, weathering), the types and amounts of impurities, and the quality and value of the recovered product. Polymer-polymer incompatability figures heavily in the available options. Therefore, we discuss separately the processing of single and mixed polymers.

Processes Using Monopolymeric Waste

When clean, segregated monopolymeric waste or scrap is available (thermoplastic only), plastic can be reprocessed directly into new plastic articles either by reextrusion or, indirectly, by depolymerization and subsequent processing to virgin polymer.

Extrusion--

Extrusion is the process of mixing and heating thermoplastic material, frequently by use of a frictional heating technique, and extruding it into objects or pellets. The monopolymeric pellets then can be used as a feedstock for molding processes that convert the raw plastic into useful articles.

During extrusion, a number of reactions may take place that degrade the physical properties of a polymer. These include decomposition, oxidation, cross-linking, and molecular weight reduction. To reduce property degradation, chemical additives may be incorporated, either identical to those used in the original material, or others if different applications are planned. Another technique used to improve the properties of reprocessed monopolymeric plastic is to blend the material with virgin polymers. The amount of material property degradation upon extrusion depends upon the thermoplastic polymer being reprocessed, the range in grades of the polymer type being mixed, the amount of contamination present in the waste material and the conditions under which extrusion occurs. In general, the process of extrusion enables plastic to be remelted and reformed, but only at the expense of property degradation. Each time plastic is heated and made to flow into a new shape, property degradation occurs. Since most plastics were extruded upon their initial forming, extruding waste plastic can be thought of as a "reextrusion" process. Without significant amounts of additives or blending, reextruded plastic can only be used for less demanding applications than was the previous polymer. Nevertheless, large markets exist for lower grade polymers.

The extrusion process typically begins with a grinding operation to reduce the plastic to a small, uniform size. After granulation, the waste plastic is washed and mineral contaminants are allowed to settle, separating from the plastics. Next, if the waste contains other polymers, these need to be separated. Finally, the purified polymer is mixed with additives and, in some cases virgin polymer, and extruded into pellets or objects.

Depolymerization--

The second approach that can be used to recycle many thermoplastic polymers is to recover the monomer or oligomers of the polymers and use these compounds to regenerate the polymers. An important advantage of the monomer recovery process is that waste plastics can be used to produce high-grade virgin polymers.

The monomer recovery process is very similar to the reextrusion process up to the extrusion stage. For monomer recovery, a chemical reactor replaces the extruder. In the reactor, purified waste plastic is depolymerized, producing reactants that can be used to manufacture virgin polymers. Two types of reactions are typically associated with depolymerization: thermally and catalytically activated reactions. Different polymer types each require unique chemical environments and/or catalysts before long molecular chains can depolymerize into their constituent subunits. Unique reactors are therefore required for each polymer, and are generally only developed when reextrusion would be infeasible, and when the total volume of recaptured monomer can be used at the same plant.

Processes Available for Specific Polymers --

<u>Polyolefins and PVC</u>--Of the polymers identified in Tables 1 and 2, the polyolefins (high-density polyethylene, low-density polyethylene, and polypropylene), and polyvinylchloride (PVC) can be reextruded with moderate degradation of physical properties. Monomer recovery processes have also been found for these polymers.

<u>Polystyrene</u>--Polystyrene has also been found to be processible by the reextrusion process. There are three types of polystyrene: general purpose; high-impact; and polystyrene foam. A study of the effect of re-extrusion on polystyrene showed that the high grade had little degradation of physical properties [13]. The general purpose grade showed moderate degradation, and foam polystyrene showed significant degradation of physical properties.

Degradation of polystyrene for monomer recovery has been accomplished using two techniques. The first technique is simply a thermal cracking process. This thermal process has been successful in yielding dimers and trimers of polystyrene [14]. These oligomers can be used as industrial additives or as prepolymers. The second method of degradation is a catalytic process [15]. This process involves the use of a silica-alumina catalyst at approximately 200^{o}C.

<u>Polyester</u>--The predominant form of polyester, polyethylene terephthalate (PET), is commonly reprocessed via reextrusion [16]. Recovery could proceed according to the flow chart outlined in Figure 3. Grinding is typically carried out by a hammermill. Separation is carried out by two processes. The first is air separation (cyclone) in order to remove paper and other light contaminants. The second consists of a sink-float separation in order to remove the other contaminants. The waste is then dried and proceeds to a shredder. At this stage the recovered waste can be put through an extruder for use in several applications. Property loss due to reextrusion is moderate, prohibiting the direct reuse of reclaimed

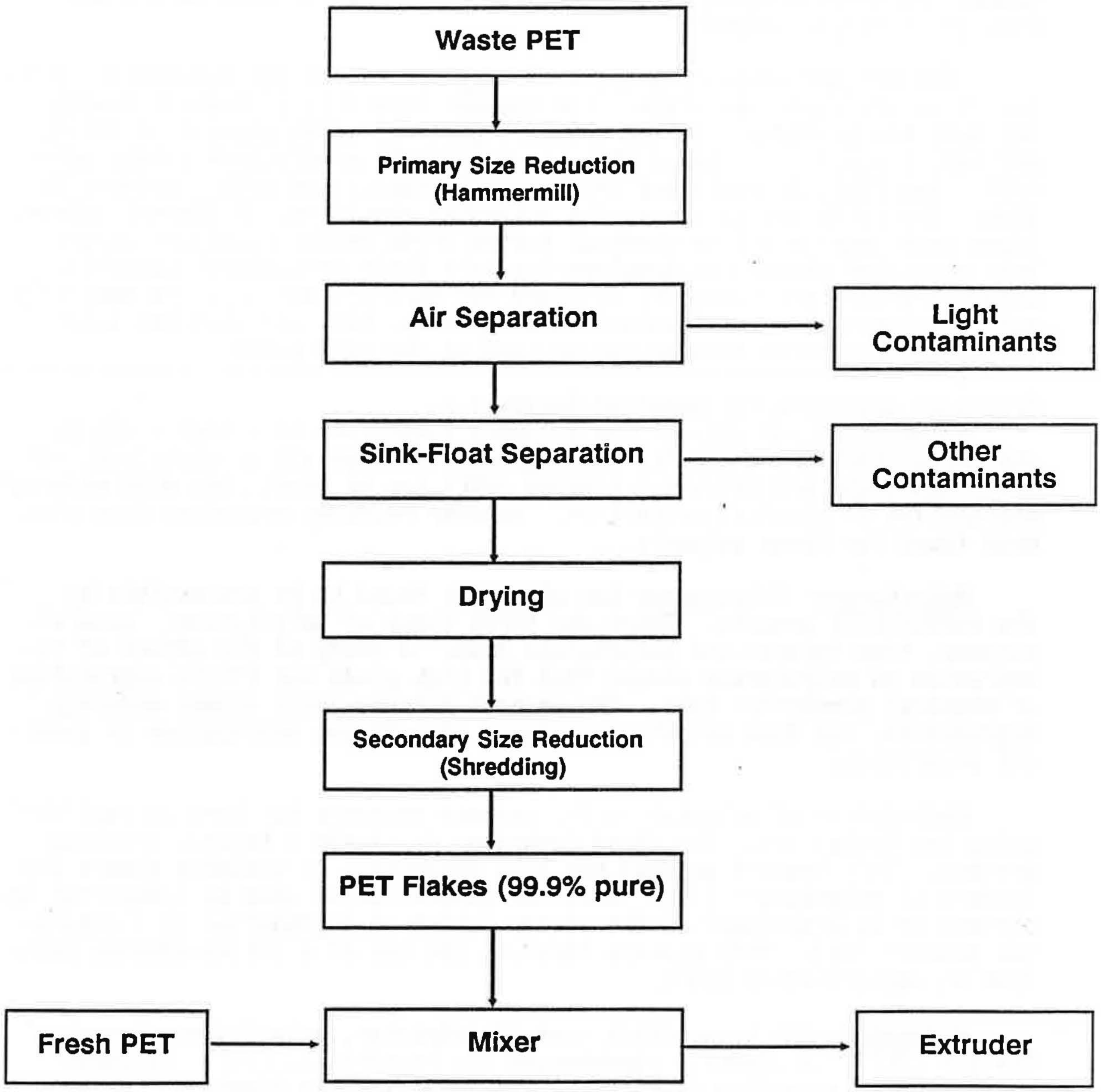


Figure 3. PET Recycling Process

PET in demanding applications such as beverage containers. However, less demanding applications exist for reextruded PET such as toys and stuffing materials. By mixing reclaimed PET with virgin polymer, compounding with additives, and other techniques, more demanding applications can be pursued. In fact, recycled PET can be blended and alloyed with other compatible polymers to produce relatively high performance engineering plastics.

Monomers can also be recovered from PET. High purity terephthalic acid can be produced by decomposition of PET in concentrated sulfuric acid, followed by precipitation and recrystallization from aqueous solutions.

Polyamide--Nylons (polyamides) are produced in a wide variety of chemical formulations, making it difficult to define a general processing strategy. Nylon 6 and Nylon 6-6 are the predominant grades in use [17], therefore reprocessing guidelines will center on these.

Fresh nylon fibers are typically spun from a reacting mixture. They are not generally found to be reextrudable, as property loss on reextrusion or respinning of fibers is unacceptable due to thermal-mechanical damage. Even at the manufacturing site, nylon waste is often reclaimed by monomer recovery.

If pure Nylon 6 is available, then recovery of its constituent caprolactam monomer is possible; the depolymerization is performed at 700^{o}C by injecting superheated steam into the molten polymer and then fractionating the products [18]. Another way to depolymerize the nylon is via continuous hydrolysis at 200^{o}C to 300^{o}C and 15 atmospheres with injection of steam, withdrawal of aqueous product stream, and final separation of products [19]; this method might possibly be extended to handle a mixture of different nylons and even polyethylene terephthelate. The difficulties entailed would be cross reaction of the depolymerization products, and separation of the products. If pure Nylon 6-6 is available, then recovery of its constituent monomers, hexamethylene diamine and adipic acid, is possible via hydrolysis [20].

One specific waste product that may be a component of marine litter is nylon/polyester fishing line. This line consists of a nylon sheath surrounding a polyester core. A recommended recovery process is shown in Figure 4. After washing and drying, the line can be cut and ground to break the nylon sheath. Polyester can be selectively dissolved using naphthalene at 200^{o}C [21]. The solution can be filtered and the nylon rinsed to ensure complete removal of the polyester. The nylon can be recovered as described above. The polyester is recovered out of the solvent via crystallization by lowering the temperature or adding a non-solvent such as water. After drying, the polyester is ready for reextrusion.

Processes Using Mixed Polymer Waste

Several techniques exist for converting mixed plastic waste into useful products. In very general terms, the processing techniques and resulting products can be described as follows:

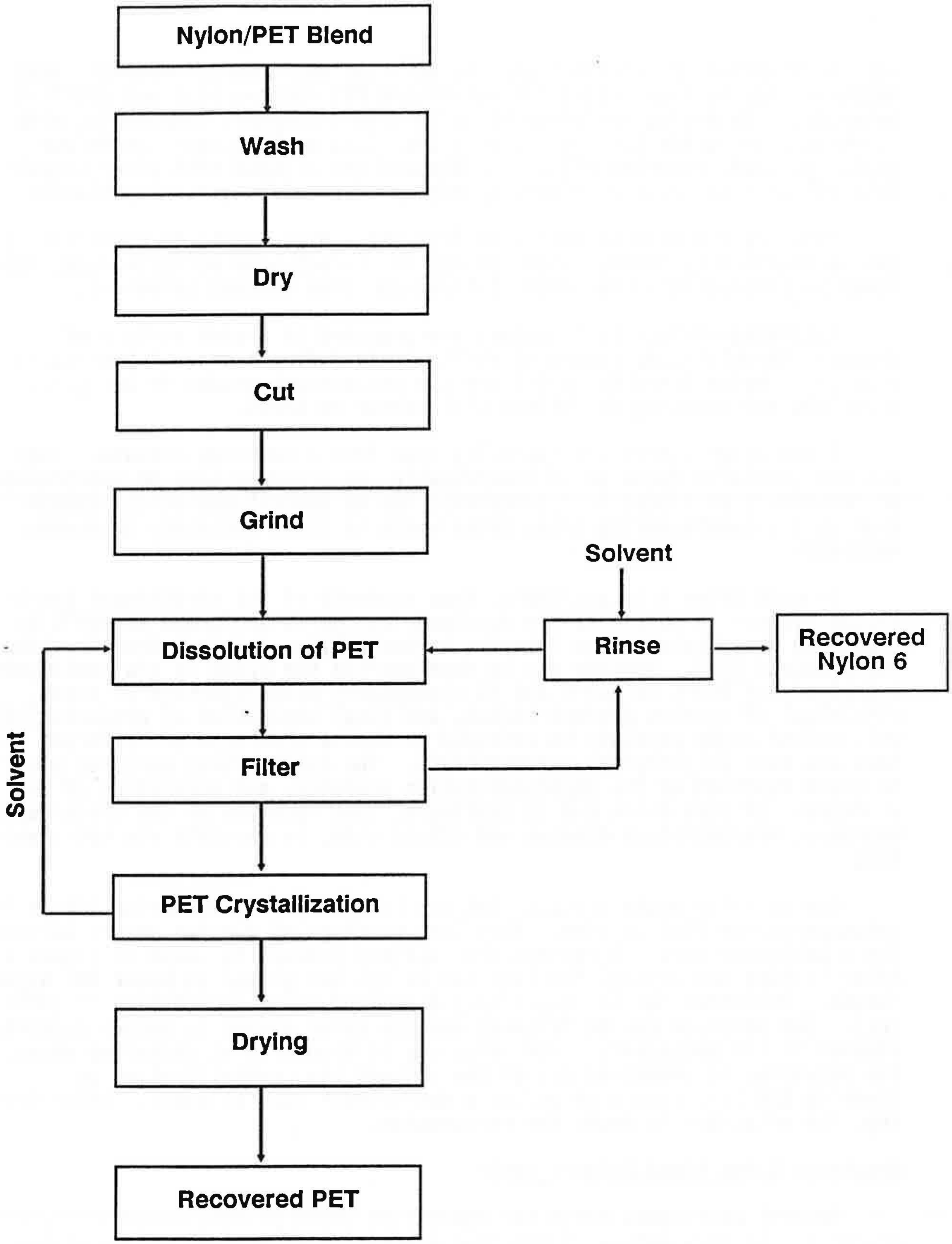


Figure 4. Nylon 6/PET Recycling Process

Processes	Products	Uses
Reextrusion	mixed plastic	thick section articles, wood substitutes
Pyrolysis	mixtures of organic compounds	fuel gases, fuel oil, chemical feedstocks,
Incineration	energy	steam, electricity

Mixed Plastics Reextrusion --

Several manufacturers in Europe, Japan, and the USA have developed extrusion equipment that is capable of processing a mixed polymer feedstock. The extrusion equipment produced to date takes advantage of the dominance of polyethylene in the plastic wastestream by heating the mixed plastic to the point at which polyethylene flows, engulfing the other incompatible polymers in a polyethylene matrix. The process can tolerate some non-plastic contamination. Additives referred to as "compatibilizers" can be added to improve the bond between incompatible polymers.

Product properties vary with the composition of the plastic feedstock. Physical properties degrade markedly from those of the dominant reextruded monopolymer as the concentration of incompatible polymers rises. As a rule of thumb, at least 50% polyethylene needs to be present in the plastic mixture in order for the reextruded product to be useful. The mixtures exhibit poor physical properties when compared to virgin plastics. To compensate for these weaknesses, reinforcing fibers can be added to improve structural properties. Typically, thick section products are manufactured and, consequently, market opportunities are limited to non-critical applications such as rot-resistant substitutes for wood. Markets for thick-section plastic products are just beginning to be developed.

Pyrolysis --

Pyrolysis is a method of thermal decomposition adaptable to either mixed plastics or monopolymers in which plastic is partially oxidized by heating in either an oxygen-free or very low oxygen atmosphere. The process is analogous to distillation and is endothermic.

Products produced by pyrolyzing waste plastic vary depending on the composition of the feedstock and the reactor conditions. In general, the reactors produce a complex mixture of combustible gases and liquids, fixed carbon, and water. The combustible gas and liquid products have heating values comparable to those of natural gas and fuel oil, respectively. With subsequent processing, products of pyrolysis could be used as a raw material for other chemical processes. A considerable amount of development work would be required to enable easily marketable fuels or other specific chemical feedstocks to be produced on a large-scale by the pyrolysis of waste plastics. Unfortunately, pyrolysis has some generally recognized disadvantages. They are:

1) compared to incineration the process is energy inefficient, consuming almost as much fuel as the process recovers;

2) product composition varies with changes in feedstock composition; and

3) large markets do not exist for the pyrolysis products.

Incineration --
Incinerating plastics along with the other components of municipal solid waste is now common practice in many parts of the world. Volume reduction and easily marketable energy recovery are the commonly cited advantages. Disadvantages of incineration are that burning may give rise to noxious gases, such as hydrochloric acid (HCl).

Despite the high energy value of plastics, it is possible to demonstrate significant energy savings through recycling rather than heat generation programs. The Plastics Institute of America has shown that, for example, 1000 lb of high density polyethylene (HDPE) has a heating value of 20 million Btu, but recycling that quantity of waste into fabricated products could save as much as 39 million Btu since 1000 lb of HDPE would not have to be made from ethylene.

Polymer Separation Processes

Several electrical and mechanical processes have been devised to separate polymer mixtures. The most common commercial process is able to separate the plastic components of PET beverage bottles, PET and HDPE, using a sink-float procedure that exploits the difference between the polymer densities. Other separation techniques exploiting either density differences or surface characteristics have been investigated, including electrostatics, air classification, magneto-hydrodynamics and object identification. Results of research into polymer separation techniques indicate that separation methods based on density or surface properties may be satisfactory for the separation of mixed, relatively pure polymers, but are unlikely to be able to separate laminated or composite plastics, or plastics that have been modified by fillers or coatings. Therefore, these methods may be useful for single source waste where the compounds of the mixture are known, but not for a complex mixture of multi-source materials. Existing polymer separation processes capable of segregating dominant polymers from complex mixtures of post-consumer plastics rely on a combination of manual and mechanical separation methods.

Section 3

REVIEW OF PLASTICS RECYCLING SYSTEMS

INTRODUCTION

With only a few minor exceptions, recyclers currently reprocess post-consumer plastic waste using reextrusion technology. Monomer recovery and pyrolysis, which are used to reprocess some waste produced at the manufacturing level, are not currently being exploited to recover post-consumer plastic waste for economic reasons.

The usual process of recycling post-consumer plastic waste consists of several stages. They are: collection, separation, cleaning, grinding, extruding and molding. In general, the fledgling plastic recycling industry is not vertically integrated from collection of waste plastics to manufacture of useful products. Instead, organizations specializing in one or several sequential stages typically sell their end product to the highest bidder. As a result, existing recycling systems may be geographically dispersed, with collection and reprocessing frequently occurring at widely separated locations.

Clean, monopolymeric plastic waste can be reprocessed with conventional extrusion equipment. Consequently, the market for reclaimed monopolymeric plastic is currently dominated by established plastic product manufacturers that substitute reclaimed plastic for all or a portion of the virgin resin used to make selected items. In contrast, the reextrusion of mixed polymer plastics or heavily contaminated monopolymer plastics requires the use of specialized extrusion equipment that has been developed in recent years. Specialty manufacturers have been formed to extrude mixed or contaminated plastics.

An important distinction can be made between plastics recycling systems in the degree to which they reduce the use of virgin materials. Ideally, recycling systems, such as those in place for aluminum and glass, are "closed loop" systems involving the remanufacture of post-consumer products into new versions of the same products, thereby displacing the need to add virgin resources. "Open loop" systems, on the other hand, involve remanufacture of a post-consumer resource into a different product. The recycling system acts as a material supply for the alternate product rather than reducing the virgin material use. Some plastic recycling systems remain greatly "open loop" in that a unit of recaptured resin may not completely displace a unit of virgin resin.

EXISTING REPROCESSING TECHNIQUES

Mixed Plastics

Mixed polymer extrusion systems that accept post-consumer plastics as a feedstock include grinding, washing, and blending operations before heating and extruding the product into molds. Commercially available equipment lines are generally automated and some can process up to 5,000 TPY of co-mingled plastic waste [22]. Tolerable non-plastic contamination depends on equipment type, but usually is in the 15% range. Production is continuous and normally occurs in batches, depending on the mold setup.

After delivery to the recycling plant, mixed plastic waste is loaded into a hopper for shredding and ground until it falls through a mesh. Ferrous material can be removed magnetically as the ground plastic moves along a conveyor belt. An optional washer, where detergent solutions remove mineral and organic contamination, can be applied to increase product quality. Next, an auger hopper dries and homogenizes the flaked plastic. At this point, additives such as "compatibilizers", pigments, curing agents, and flame retardants can be blended in. Once the plastic waste is ground, washed, and amended it is ready for the key phase of treatment: plastification and extrusion. An adiabatic, high-shear screw heats the plastic granulate frictionally, causing the mixture to soften and blend. The melted plastic blend is forced through an extrusion head and then compressed into molds that lie on a rotating table. Finally, the warm, soft products are water-cooled and set out to harden [22,23].

The synthetic products produced by reextrusion technology have found a wide range of applications, especially in the form of rot-proof wood replacement items. Livestockmen have purchased synthetic planks and posts for use as corrosion- and chew-proof pig pens, horse stalls, and feeding bins. Marina builders like the seawater- and organism-resistant piers and decking for dock construction. Pallets, grates, industrial flooring, planters, curbstones, bins, and soil retainers can all be made out of waste plastic, with the benefit of being more sanitary, durable, and weatherproof. These products can be cut and fastened just like wood and will never require painting or finishing. Since the present technology yields downgraded plastic qualities, product applications have been restricted to those mentioned above and to similar low demand items. Due to the multipolymer aggregate nature of these synthetic materials, product thickness has been restricted to a minimum of 4 mm (thick section products) [22].

The first commercially available mixed polymer extrusion equipment line was the Reverzer, developed about a decade ago in Japan by the Mitsubishi Petrochemical Co. The Reverzer was imported to Europe and, through a series of refinements, led to the development of the current generation of machines. Advanced Recycling Technology Ltd. of Belgium manufactures the ET/1, one of the most popular models. Currently, 20 of the ET/1 extruder equipment lines are actively producing a saleable product in western Europe and the U.S. [24]. Other prominent extruders include Recycloplast (W. Germany) and Revive (Italy). Several other organizations are developing mixed plastic extruders for their own use and/or for sale [25-30].

Monopolymer Plastics

Out of the billions of pounds of post-consumer plastic generated annually, a mere 1% is recycled into useful consumer products. PET carbonated beverage containers and HDPE milk jugs compose the majority of this recycled plastic, and together represent the vast majority of the over 150 million pounds of post-consumer monopolymeric waste recovered in

1987 [30]. These beverage containers are a source of pure polymer type and, therefore, can be reextruded into higher grade and more valuable products than is possible with mixed polymer feedstock.

PET bottle reprocessing systems, spurred by the sudden supply of PET feedstock in U.S. states having bottle bills, have become established by at least 16 independent businesses as listed in the Plastic Bottle Institute's Plastic Bottle Directory and Reference Guide of 1987 [31]. These companies remanufacture ground, washed PET flakes into saleable products; primarily fiberfill stuffing for garments and sleeping bags, urethane polyols, and unsaturated polyester. The latter two products are chemicals used in the manufacture of rigid plasticized items such as boat hulls and refrigeration insulation. In addition to remanufacturers, at least 20 listed companies in the U.S. are involved with PET recycling, either as brokers who buy and sell empty bottles or as intermediate processors who buy, regrind, clean and sell PET plastic to remanufacturers. Some companies, such as Wellman, Inc. (South Carolina) and St. Jude Polymer (Pennsylvania), are involved with all aspects of PET recycling and, in fact, account for the great majority of the U.S. reprocessing capacity [32,33].

A complete technology transfer license agreement for PET bottle recycling is available through the Center for Plastics Recycling Research (CPRR) at Rutgers University in New Jersey [34]. The agreement contains comprehensive technical and economic information that would allow a potential recycler to pattern his PET bottle reclamation system on the proven facility developed at CPRR. The system basically involves granulating, removal of paper and plastic labels using air classification, detergent washing, flotation separation of HDPE base cups and PET bottle material, spin drying, and separation of the aluminum from the PET using electrostatics [31]. Equipment components are commercially available through manufacturers also listed in the Plastic Bottle Recycling Directory. Clean PET flake emerging from the above machinery is currently valued at about $0.25 to 0.30/lb if clear, and slightly less if green (roughly one half of virgin PET prices). Recycled plastics have not been subjected to testing required to enable U.S. Food and Drug Administration (FDA) approval for food-contact use. As a result, recycled PET and other recycled plastics cannot be reprocessed in the U.S. to produce food or beverage containers. Nevertheless, numerous uses have been found for recycled PET, including the production of fiberfill, appliance and automotive parts, cargo strapping, blow-molded non-food packaging, roofing material, and earth-retaining "geotextiles" [35,36].

Blow-molded HDPE containers, including milk jugs, motor oil, antifreeze, and bleach and detergent bottles are currently produced at the rate of 2.2 billion lb/yr [37]. This figure is roughly four times higher than PET bottle production and yet HDPE recycling lags behind PET recycling. The primary sources of HDPE, plastic milk jugs and base cups recovered in PET recycling are currently being purchased in the U.S. by 24 listed businesses, nine of which also remanufacture the HDPE into marketable end products. Most of these companies have been involved with recovery of plastic scrap resulting from plastic manufacturing processes, an industrial byproduct not generally viewed as a waste material. Post-consumer HDPE bottles generally can be reclaimed using the existing or slightly modified industrial HDPE recovery equipment and, therefore, plastics companies have been willing to purchase post-consumer HDPE from independent collectors.

HDPE reclamation equipment is similar to the PET systems but is simplified since HDPE bottles have no base cups or aluminum closures to separate. The process involves granulation and washing to remove labels, adhesives and contamination, sometimes followed by pelletization. Washing techniques have been improved by several processes and now are refined enough to produce HDPE flakes that meet the same specifications as industrial scrap regrind and reprocessed virgin resins. Pelletization, using standard, well-developed equipment involves melting, extruding, waterbath cooling, and chopping. Market-ready HDPE pellets are produced, which then can be shipped to manufacturers who accept recycled HDPE feedstock. Manufactured items include drainage pipe, drums, pails, toys, plastic lumber, and new PET bottle base cups [35].

Economics of Reprocessing

Mixed plastic recycling systems may be conceptually attractive, and certainly are technically feasible, but current economic factors limit their use in the American market. To illustrate the financial viability of reprocessing mixed plastics, Table 3 presents an estimate of capital and operating costs for three mixed plastics extrusion equipment lines, ignoring any cost for the purchase of feedstock. For the purpose of this simplified analysis, the estimated unit production costs are roughly the same for the three systems. Unfortunately, revenue potential for the products of these systems is unknown. Market analyses are being performed by several groups but, for the time being, estimates of revenue potential fall into a range of $0.15 to $0.50/lb, being heavily dependent on production quantities. Two primary economic factors, raw material supply and product market development, remain as the impediments to successful economic operation of a mixed plastics reextrusion facility. Unless a reprocessing facility can operate at or near capacity, operating economics deteriorate markedly. An abundant and steady source of mixed plastics would be required to supply a mixed plastic processing system. Such a supply would be too costly for the extruder owner to separate and collect, and municipalities have yet to implement widespread plastics source-separation and collection schemes. Product market development remains juvenile, and a sales rate equal to the equipment production rate at full capacity would be questionable at this time.

The two most common commercially available mixed polymer extruders have significantly different capital cost and operating characteristics. The ET/1 is a comparatively inexpensive, low-capacity, "off the shelf" extruder. The Recycloplast, on the other hand, is a more expensive, high-capacity integrated system that can be customized to accept and blend a wide range of polymer types [22-24,30]. The ET/1 can also blend polymers and produce upgraded products, but the Recycloplast's automated bank of ingredient hoppers allows it to more easily produce a greater range of upgraded products. The three systems can produce plastic products at an estimated cost of $0.17 to $0.25/lb before profit; however, cost will vary depending on feedstock, marketing and other expenses. This production cost is similar to the price at which a lumber-like plastic product

TABLE 3. SUMMARY OF ESTIMATED UNIT COSTS AND REVENUES FOR THREE MIXED PLASTIC REEXTRUDER FACILITIES

	ET/1	Recycloplast	Revive
Total Capital Cost	$430,000	$5,000,000	$360,000
Capacity[a)]	400 lb/hr	1400 lb/hr	270 lb/hr
Capital Recovery Cost ($/lb)[b)]	.03	.10	.04
Operating Cost ($/lb)			
Labor[c)]	.05	.04	.05
Utilities	.05	.04	.04
General & Admin.[d)]	.02	.02	.02
Maintenance & Ins.[e)]	.01	.04	.01
Rent[f)]	.01	.01	.01
TOTAL ($/lb)	.17	.25	.17
Revenue ($/lb)	0.15 - 0.50	0.20 - 0.60[g)]	0.15 - 0.50

Assumptions:

a) Process is 80% efficient

b) Term: 10 years, Interest rate = 10%

c) Labor $20,000/Employee/yr
- + 30% fringe benefits
- 3 shifts/day for continuous production
- 300 working days/yr

d) G&A is assumed and does not include provision for profit

e) Maintenance is 5% of capital cost. Insurance is 1% of capital cost

f) Rent $5/ft^2. ET/1 and Revive require approximately 5,000 ft^2. Recycloplast requires approximately 20,000 ft^2.

g) Unlike the ET/1 and Revive systems, the more expensive Recycloplast system has the ability to automatically blend input plastics in order to meet a given product specification. As a result, its products may have a slightly higher revenue potential.

becomes competitive with pressure-treated lumber. Higher value products, such as waterproof containers and crates, could sell for substantially higher prices, but at much lower volumes than plastic lumber.

Historically, the development of mixed plastic extruders was spurred by a perceived need to reduce the amount of non-degradeable waste being landfilled rather than by the need for non-degradeable wood replacement items. In this sense, the remanufactured plastic products usually enter a market already dominated by wood -- in some locations a cheap and abundant resource. In Japan and western Europe, however, wood is more scarce and valuable than in North America, and the plastic lumber has a growing competitive edge [23]. America still has substantial reserves of lumber and, therefore, the more expensive synthetic alternative products may not compete as well in the established lumber markets. Recycled plastic lumber may find a market niche in specialty applications such as animal pens, marinas and fence posts where rot resistance would be highly valued. This market has yet to be developed, but could theoretically provide a substantial outlet for the recycled plastic. Similarly, the hundreds of product ideas listed by promoters of these mixed plastic extrusion machines could provide markets given sufficient market research and development.

PET bottle recovery currently operates under economic conditions more favorable than mixed plastic recovery, primarily due to the preexisting industries that purchase large volumes of PET. The Plastic Bottle Institute estimated that the 1985 market potential for products that could be made from recycled or virgin PET to be over ten times the amount of PET recycled [35]. Sufficient outlets for recycled PET exist, but the total cost of recycling PET remains higher than the current market price of reprocessed PET. Collection remains as the major inhibiting expense and all successful PET recovery systems are operating under some form of collection subsidy. Ignoring collection costs, large volumes of PET must be available before reprocessing becomes economically feasible, and such volumes are presently gathered only in states with bottle bills in place.

According to research performed at the Center for Plastics Recycling Research, a PET recycling plant can become economically feasible when the processing volume reaches 10 million lb/yr, assuming a clean, clear flake can sell for $0.25/lb. Feedstock costs are currently $0.05 to $0.10/lb for baled bottles, depending on the level of contaminants and/or color. A 10 million lb/yr PET bottle processing plant would cost between $2 and $2.5 million to construct, and would include all the equipment necessary to produce a clean (99.9% pure), clear PET flake. The most costly operational aspect of this plant would be the manual removal of green PET and non-PET bottles from the clear bottle stream. The current prices for reclaimed PET that has been cleaned and ground are generally in the range of $0.25 to $0.30/lb. Clear PET usually commands a slightly higher price than do colored grades. For comparison, the current price for virgin prime grade PET is usually in the range of $0.55 to $0.60/lb.

Ignoring the avoided cost of disposal, the direct costs of collecting, crushing, baling and shipping PET to reprocessors is much higher than the $0.05 to $0.10/lb currently being offered by processors for baled bottles. The California Department of Conservation has estimated this intermediate processing cost to be $0.36/lb for PET collected as part of the California bottle bill and has required plastic bottle manufacturers to shoulder the cost. In the nine other bottle bill states, retailers, distributors and bottlers end up sharing the cost of intermediate processing. Similar handling costs have been estimated by various sources in other states that have bottle bills, typically $0.02 to $0.04/bottle, or roughly $0.20 to $0.40/lb of plastic bottles.

Future markets for recycled PET look bright as new technologies and innovative uses for recycled PET come into more widespread use. According to the Plastics Recycling Foundation, unexploited uses of PET include blow-molded non-food packaging, carpet backing, multi-layer food packaging, and compounded PET hybrids [32]. For high-priced applications, recycled PET alloy resins have been developed that can compete with some engineering thermoplastics.

HDPE recycling operates under similar economics as PET recycling in that collection and intermediate processing is more expensive than the scrap value of HDPE, but once reprocessors obtain a sufficient annual volume of crushed or shredded HDPE bottles at the current market value, reprocessing can be profitable. Since bottle bill legislation has applied only to carbonated beverage containers, HDPE milk jugs have not been collected or gathered in the same way as PET bottles. The small fraction of post-consumer HDPE that is purchased by plastics remanufacturers is usually collected through small non-profit recyclers or through drop-off programs.

Similarly to PET, the market price of baled, post-consumer milk jugs ranges from $0.05 to $0.10/lb. Colored HDPE bottles, such as antifreeze and bleach containers, have a similar scrap value, but this market is even less developed than the milk jug market. Processing costs to produce a clean HDPE flake are slightly less than those for PET since HDPE bottles do not require separation of a base cup, equipment, or, depending on products produced, manual sorting of colors from clear bottles. Due to the proprietary nature of HDPE cleaning and processing systems, the actual costs are not known. Granulation machinery is readily available, but washing equipment and specialized detergent solutions remain the key to reprocessing HDPE. Clean and reasonably pure HDPE flake can be sold for $0.17 to $0.20/lb, and if the flake is further processed into pellets, the value can rise to $0.32/lb, depending on polymer purity. Virgin HDPE pellets currently sell for about $0.40/lb and, therefore, manufacturers of high volume and low margin plastic products can enjoy a substantial raw material savings by using recycled HDPE, if the reclaimed material can meet their performance needs. According to Andrew Stevens of Eaglebrook Plastics, Inc., sufficient markets for HDPE exist, which could absorb all of the potentially recyclable HDPE.

A summary of typical prices for reclaimed PET and HDPE in various forms is presented in Table 4. Historically, reclaimed HDPE and PET that are ready for use as a virgin resin substitute have sold for one-half to three-quarters of the virgin resin price. The price differential reflects property degradation of reclaimed materials compared to virgin resins.

TABLE 4. COMPARISON OF BULK PRICES FOR SCRAP AND VIRGIN PET AND HDPE PLASTIC

Grade	Bulk Prices ($/lb)[a]	
	PET	HDPE
Virgin, Prime (Pellets)	55 - 60	40
Clean, Reclaimed (Ground)	25 - 30	17 - 20
Post-consumer Bottles (Baled) with 10% Contamination	5 - 10	5 - 10

a) Based on an informal survey of intermediate processors and brokers in March 1988.

Limitations of Analysis

Comparing the direct cost of collecting and reclaiming post-consumer plastics with the current market prices offered for reclaimed materials indicates that post-consumer plastic recycling is not financially feasible. While this type of financial comparison would be appropriate for an entrepreneur considering the development of an operation to collect and reclaim post-consumer plastics, the analysis is not an adequate judge of overall economic efficiency. Several generally recognized external factors influence the present financial feasibility of plastics reprocessing.

Firstly, the analysis ignores the avoided cost of waste plastic disposal. Typically, no mechanism exists to transfer the avoided cost of waste disposal to those who would collect and prepare post-consumer plastic for reuse. Moreover, when avoided costs can be transferred, landfill disposal fees, in most places, are currently set far below the marginal cost of current alternative disposal or recycling technologies. Low landfilling fees indirectly promote the use of virgin materials because landfilling is a complement to the use of virgin materials and a substitute for recycling. Current waste disposal prices reduce the incentive to collect materials that can be recycled by preventing some of the social savings of recycling from flowing to the firms and those individuals who do recycle.

Tax laws also favor the continued development of the virgin materials industry with tax credits given for depletion allowances being met, exploration and development costs, foreign tax credits, and capital gains. The preferential tax treatment that virgin materials receive is a factor which lowers the market price for virgin materials.

Procurement guidelines (and our society in general) favor the use of products that are new (virgin), even if reclaimed materials can fulfill the same uses or meet the same specifications as do virgin products. Both government and non-government procurement guidelines have historically been written with a bias toward virgin materials.

Environmental regulations set at national, state, and local levels are more stringent for secondary materials than virgin materials because they are generated and processed in urban areas that are very visible to citizens and lawmakers. This inequality in regulatory processing results in a higher price for the secondary materials since the cost of bringing the materials within the regulatory limits is higher.

Finally, economies-of-scale and transaction costs are important to both the production of virgin materials and the reclamation of wastes. The fledgling plastic recycling industry must compete with both established virgin materials industries and an established waste disposal industry that are currently exploiting enormous economies-of-scale compared to that of recyclers. Furthermore, because reclaimed plastics are not yet recognized as a commodity, as are virgin polymers, transaction costs are much higher for reclaimed materials.

PLASTIC COLLECTION PROGRAMS

Despite the high cost of reclaiming post-consumer plastic compared to the current revenue potential from the sale of reclaimed materials, a small amount of plastic is being collected and recycled. As stated in previous sections, the vast majority of the post-consumer plastic recycled in the U.S. is PET beverage bottles collected as a direct consequence of state legislation (bottle bills). PET also appears to be the most commonly collected post-consumer plastic in Canada, spurred by Provincial and local recycling legislation. Bottle bills encourage the recycling of beverage bottles by creating an artificial redemption price for each bottle and establishing a collection system. With the exception of PET, worldwide, no large-tonnage plastic recycling scheme has yet been successfully commercialized.

Another minor but growing source of post-consumer plastic is curbside collection programs. Curbside collection programs have been established in many American, Canadian, and European cities as a result of local government regulations or influence. The programs have generally been motivated by regional landfill space shortages or the perception that available landfill space is limited. However, only a very small minority of curbside collection programs include plastic as a collected material. A survey by the Massachusetts Division of Solid Waste [38] found only 16 North American cities having curbside collection programs that included plastics. Most of these programs are in small communities, with the main concentration in the Midwest where reclaimed plastics markets are more developed. Collections are typically limited to PET bottles, milk jugs and, sometimes, other HDPE.

Much larger quantities of post-consumer plastics are being recovered by curbside collection programs in Europe. Most of the European curbside activity is centered in West Germany, Belgium, and the Netherlands and is based on an expansion of the West German "green bin" system. This system uses two carts from which household waste is collected at curbside: a black bin for wet wastes (compostables) and a green bin for the remaining dry wastes. The dry wastes are taken to material processing centers at which mechanical and manual sorting operations recover recyclables, including plastics, for market. Some cities have modified the curbside system to include a separate plastic bag for the collection of source separated plastics, in addition to the green and black bins.

As far as plastics recycling is concerned, the main difference between European and North American curbside collection systems is that European programs recover plastic film in addition to rigid containers. It is this steady supply of polyethylene-rich mixed waste plastics that helped encourage the development of mixed plastic extrusion equipment in Europe.

A third source of plastics is drop-off facilities operated by local recycling organizations. A drop-off facility basically consists of a collection of bins into which recyclable materials can be discarded by type. The bins are placed at fixed locations requiring the consumer to transport recyclables to the facility. As with curbside collection programs, drop-off facilities accepting plastics are relatively rare and, in order to minimize transportation costs, are typically located near plastics reprocessors that purchase post-consumer plastic scrap.

Several experimental plastics collection and recycling systems have been developed in recent years to generate cost and product quality information. The largest investigation, sponsored by the British Plastics Foundation, was a multi-location drop-off collection system referred to as the PET-A-BOX project [39]. The project operated eight drop-off containers at separate locations in the cities of Bradford and Leeds between 1981 and 1986. PET was selected for the experiment because of its comparatively high volume and ease of identification. In order to develop consumer participation and minimize non-PET contamination, publicity and consumer education were made integral parts of the project. After five years of operation, the project collected 40 tons of PET with an average contamination level of about 10%. The operating cost of emptying the boxes and baling the material averaged approximately £650/ton ($0.40 to 0.50/lb). This compared with a market value of $0.05 to 0.10/lb for baled PET bottles.

In many parts of the Third World, waste plastic is routinely recycled into low grade products such as buckets, bowls, hoses, and pipes [40]. The industries operate without subsidy and are based on monopolymer reextrusion, using the abundant low-cost labor to collect and sort plastics by polymer type. Unlike the situation in industrialized countries, plastics reprocessors in the developing countries are not reluctant to cut their raw polymer costs at the risk of production delays caused by feedstock contamination.

The collection process starts with scavengers, who collect mixed recyclables from the streets, refuse dumps, or other sources and separate the materials by hand. They separate film from solid objects and carry out cleaning when necessary. Figures 5 and 6 show waste plastic being cleaned and dried by scavengers in a developing country. Cleaned and separated plastics are sold to intermediate processors who wash, granulate and sometimes compound and pelletize the materials using machinery designed and built in Third World countries for the Third World market. The equipment is simple, rugged, and functional, but typically lacking in safety features.

In general, plastics recycling in developing countries is not limited by labor or capital costs. Volger [40] reports that the factor limiting recycling seems to be availability of sufficient material.

Other monopolymer recycling operations have been established in rapidly developing countries such as Hong Kong and Taiwan. Like recycling in Third World countries, these operations seem to be based on an abundant source of very low-cost labor.

REGULATORY ENVIRONMENT

Interest in the recycling of plastics has been increasing in recent years. In many parts of the world, lawmakers have become aware of a sense of urgency surrounding solid waste issues. It is not surprising that governments become concerned and consider direct intervention when the major

Figure 5. Sorting and Cleaning Waste Plastics by Hand

Figure 6. Air-Drying Waste Plastic for Reprocessing

share of growth for the plastics industry comes from the manufacture of throw-away items, the disposal of which is the responsibility of the public sector. As a result, a considerable amount of legislation has been enacted recently worldwide that affects the recycling of post consumer waste plastic.

Governments have crafted regulations that impact the plastic waste issue from three approaches. They are:

1. Techniques to reduce plastic waste quantities;

2. Techniques to increase the diversion of wastes into recycling channels; and

3. Techniques to increase the demand for recycled materials.

In this section, we present a brief summary of existing and proposed laws that stimulate recycling efforts. A more comprehensive description of recycling regulations, either in effect or being considered in the U.S., is presented in the Appendix A; Review of Regulatory Environment.

Waste Reduction Techniques

Plastic waste reduction legislation has been enacted or considered in many locations over the last twenty years. More recently, statutory bans have been enacted prohibiting the use of certain non-degradable plastic items such as non-degradable plastic foam food containers and six-pack ring containers. Related laws include waste abatement programs that enable governments to take action against the manufacturers or distributors of certain products or packaging materials that are disposed of and are found to be incompatible with solid waste management policy. Legislation has also been advanced to tax each product packaged in non-recyclable or difficult to recycle materials.

Another form of waste abatement laws are those that prohibit or limit the disposal of certain materials in landfills, incinerators, or both. Disposal restrictions and prohibitions function to reduce the generation of restricted wastes, while at the same time encouraging the recycling of those materials. Several states propose to ban plastic from landfills and/or incinerators. Laws to prohibit the disposal of plastics in the marine environment, such as those in California and the MARPOL ANNEX V International Treaty, have a similar dual effect, although they only affect specific groups of waste generators.

Recycling Supply Techniques

Container deposit laws (bottle bills) have shown to be a direct way of diverting a portion of the waste stream into recycling channels. Bottle bills have been enacted in at least ten U.S. states, one Canadian province, one country in Europe, and one Australian state. Several other countries are considering container deposit laws. Presently, bottle bills are directly responsible for nearly all post-consumer PET recycling. As currently written, bottle bills usually apply only to carbonated beverage bottles, which represent a small fraction of the plastic waste stream. A proposal has been advanced in California to expand the scope of that bottle bill to include much more of the plastic waste stream.

Another recycling supply strategy is legislation that makes recycling of certain materials mandatory. Mandatory recycling laws have been written in several forms, specifying recycling quantity goals, the waste collection channel to be established (usually curbside), or both. For example, the "green bin" program, which was pioneered in West Germany, established a curbside system to collect source separated materials. Similarly, many North American cities have established mandatory curbside collection systems. Laws that establish recycling goals rather than specifying a collection system usually have the same effect, encouraging the establishment of source separation and curbside collection programs. The largest recycling program in the U.S. was recently established with passage of the New Jersey Statewide Mandatory Source Separation and Recycling Act. This law established recycling quantity goals, but leaves the counties and municipalities to plan and develop their own strategies for collection and marketing of recyclables.

Finally, public grants, loans, and public/private partnerships have been used to help establish plastic processing facilities. All of the mixed plastic extrusion machines currently operating in the U.S. have been purchased or developed with financial aid from public or industry sources.

<u>Recycling Demand Techniques</u>

The most significant regulatory action taken to increase the demand for recycled products is the changing of government procurement standards. In many ways, government procurement standards have been written to give preference for products made from virgin materials. Recognizing this bias and importance of the government market, Congress (through the Resource Conservation and Recovery Act) directed the EPA to issue government procurement guidelines for five recycled materials by 1978. So far, guidelines for only two materials have been issued. Sixteen states have passed laws mandating preferential treatment for products with recycled content; however, most of those laws only address paper.

KEY FACTORS AFFECTING THE SUCCESS OF RECYCLING SYSTEMS

Waste plastic can be reprocessed into useful products via several demonstrated techniques. However, in the industrialized world, very little post-consumer plastic is recycled for reasons of fundamental economics: the cost of collecting and processing waste plastic to the point at which it can be sold as a product or a reclaimed feedstock exceeds the prices those products or reclaimed materials can fetch on the market.

Under some existing circumstances, the relationship between collecting and processing costs and product revenue is such that a sufficient profit margin exists, making recycling worthwhile to private firms. As discussed in previous sections, for example, recycling is common practice for post-consumer plastics in many Third World locations. Compared to the economics of recycling in industrialized countries, there is more room for profit in developing countries. Firstly, low labor costs in developing countries result in a lower cost of collecting and processing waste plastic compared to that in the industrialized world. Secondly, the price of recycled plastic products remains comparably high because direct substitute products or materials (virgin plastics) are imported from the industrialized countries.

Reprocessing is also routine practice for pre-consumer plastic waste in both developing and industrialized countries. Compared to the economics of post-consumer plastic reprocessing, pre-consumer plastic waste is easier and cheaper to collect and process for reuse. Moreover, the avoided cost of disposal is a real cost for a manufacturer faced with the choice of disposing or reclaiming plastic scrap. By reprocessing plastic scrap, a manufacturer avoids the cost of disposal.

The largest existing systems for the recycling of post-consumer plastics in the industrialized world are based on direct or indirect regulations that reduce or subsidize the cost of plastics collection or transfer the collection cost burden to other industrial segments. Curbside programs are an example of collection cost reduction and subsidization. Curbside collection systems usually collect several source separated recyclables, sharing the gross collection costs among several materials, thereby reducing the cost for each. Curbside programs may also be subsidized by property or other taxes, some of which may represent a transfer of the avoided cost of disposal.

Bottle bill programs are an example of systems that transfer the cost of collecting recyclables to manufacturers, distributors, and/or retailers. Again, as with curbside programs, bottle bill programs collect bottles made of several materials, sharing the cost of collection among several different material types.

Perhaps the most important factor affecting the economics of plastic recycling is the great diversity of mutually incompatible polymers generally found in the waste stream. Plastic products are made from a variety of polymers and, frequently, individual articles represent a composite of several polymer types and even other materials. The economics of plastic recycling depend on the heterogeneity of the polymer types in the waste stream. The mechanical performance and resulting value of reextruded mixed plastics degrades markedly as plastic composition departs from that of a pure polymer type. Similarly, the cost of collecting and separating mixed plastics for reclamation as pure polymer types rises as waste plastics become more heterogeneous. The ability of designers to reduce the cost and increase the performance of articles and packaging by choosing from a wide range of polymer types, has led to an increase in the cost of recycling the plastic waste stream. Industrial product and packaging concerns, therefore, are at the "front-end" of the recycling economics problem and through product and packaging design, could significantly improve the economics of recycling.

In one rare example of industrial cooperation in producing more easily recyclable plastic packaging, Coca-Cola Germany, Desmacon (a Netherlands petrochemical company and PET bottle producer) and Reko (Desmacon's plastic recycling subsidiary) have successfully introduced into West

Germany and The Netherlands a PET bottle that is designed specifically for recycling [41]. Coke, Desmacon and Reko coordinated research and Desmacon developed a 2-liter bottle with a standard size and shape for all of Coke's carbonated beverage products. Clear PET was used for all bottles, including the innovation of a clear PET base cup. Small paper labels were applied with water soluble glue, and non-aluminum caps (polypropylene) were developed. These changes simplified the PET plastic reclamation process and enabled a higher purity plastic to be collected. The high-purity PET was more valuable than PET collected from standard bottle designs, improving the economics of recycling. The PET was also more marketable because a wider variety of uses exist for cleaner materials. Coke, Desmacon and Reko promoted a public education campaign and introduced the bottle with a deposit in place. After fourteen months, recycling rates were 70% in West Germany and 73% in The Netherlands [41].

Section 4

RECYCLING PLASTICS FROM OCEAN VESSELS

CURRENT AT-SEA DISPOSAL PRACTICES

Plastic waste enters marine waters from both terrestrial and offshore sources. Unfortunately, the total waste quantities and the proportion from terrestrial and offshore sources are not accurately known. Evidence from beach cleanups indicates that a substantial portion of plastic litter comes from ocean vessels. It is generally believed that the vast majority of waste plastic in marine waters comes from unregulated dumping from vessels.

At this time there are several waste management techniques being used on board ocean vessels. For vessels plying international waters, the most commonly used method of solid waste disposal is to throw plastic trash bags of unprocessed refuse off the ship in international waters. The other solid waste management techniques are based on the use of processing equipment to enable waste to sink when discharged overboard.

Storage limitations and waste generation rates vary among the several classes of ships. This section addresses the waste disposal efforts of three categories of vessels: 1) cruise ships and U.S. Navy ships; 2) small ferry boats, pleasure craft, and fishing boats; and 3) freighters, tankers, container and automobile transport ships.

Cruise Ships and U.S. Navy Ships

Most of the cruise ship companies and the U.S. Navy have implemented waste-control procedures. These procedures enable either on-board storage of wastes or overboard discharge of processed wastes.

Waste generation rates for these heavily populated vessels are high and waste comes from several sections of the ship. Total waste generation rates have been estimated by the U.S. Navy to average 3 lb/person/day (2 lb of dry refuse and 1 lb of high-moisture content food wastes). Of this, approximately 0.2 lb/person/day (approximately 7%) has been estimated to be plastic. Waste generation rates on cruise ships are even higher. One estimate gives a total generation rate of 2 Kg/person/day (4.4 lb) [42].

Table 5 presents the major waste components and daily amounts (averaged over a week cruise) generated aboard a cruise vessel with approximately 1,000 passengers and a crew of 500 [43].

Composition and generation rates for another cruise ship with 2,000 passengers and a crew of 800 are shown in Table 6 [42].

TABLE 5. SELECTED WASTE COMPONENTS AND DAILY AMOUNTS GENERATED ON BOARD A 1,000 PASSENGER CRUISE SHIP (AVERAGED OVER A ONE-WEEK CRUISE)

Item	Percent of Waste Stream	Mass/Day (kg)
Garbage	50	86
Engine Room Wastes	25	430
Glass Bottles	8	14
Cardboard	8	140
Miscellaneous (including plastics)	8.4	150
Aluminum Cans	0.6	11
TOTAL	100.0	1,731

TABLE 6. SELECTED WASTE COMPONENTS AND DAILY AMOUNTS GENERATED ON BOARD A 2,000 PASSENGER CRUISE SHIP

Item	Percent of Waste Stream	Mass/Day (kg)
Burnable Refuse	68	3,200
Plastic	5	260
Garbage (pulped)	13	610
Glass	9	420
Metal Cans, Etc.	5	260
TOTAL	100	4,750

Unfortunately, these composition surveys used different definitions of the components in the waste stream. As a result, the component proportions are not directly comparable. However, the studies by Norsk Hydro [42] and the U.S. Navy indicate that the proportion of plastic found in ship-generated waste, 5% and 7% respectively, is similar to that generally found in terrestrially-generated municipal solid waste.

Space limitations on Navy and cruise ships have a controlling influence on the way solid waste is handled. Generally, these vessels have been designed for a waste storage capacity of up to three days of waste generation under normal operating conditions. After three days, waste in a cramped ship become highly objectionable and must be treated or discharged. Compacting and baling all or a portion of the waste stream is common practice for many vessels, both to increase the effective storage capacity and enable wastes discharged to immediately sink.

Grinding and pulping waste is another technique used by some vessels to enable putrescible wastes to be stored in tanks, which are sealed off from habitable spaces and ultimately discharged overboard.

Normally, a ship arriving from a foreign port that unloads refuse on land must comply with regulations for disease protection and for solid waste disposal. For vessels plying international routes, solid waste generated aboard the vessels is considered to be of foreign origin by the country the ship is visiting. Stringent and costly procedures are required for the solid waste that is considered to be of foreign origin if the waste has had contact with foodstuffs or certain other animal and plant wastes. For example, in the U.S., solid waste of foreign origin that has also come in contact with foodstuffs must be disposed of according to U.S. Department of Agriculture (USDA) requirements for quarantine of imported goods. The three USDA-approved on-shore disposal methods are as follows:

1. The solid waste must be thermally sterilized at a minimum temperature of 212°F for 30 minutes and the residual must be buried in a sanitary landfill.

2. The waste can be burned in an incinerator approved by the Environmental Protection Agency (EPA).

3. The solid waste can be pulped and piped into an on-board holding tank and subsequently discharged into a sanitary sewer in port as long as the sanitary sewer is connected to a shoreside disposal system approved by the USDA for receiving foreign wastes.

Therefore, at least in the U.S., plastics aboard ship that have had contact with foodstuffs (particularly meat and dairy products) are not eligible for recycling on shore. However, if the plastics are source-separated and have not come into contact with foodstuffs, the plastics would be eligible for recycling.

Unloading refuse onto land can be accomplished either at dockside or while a vessel is at anchor. In either case, a barge is commonly used to transport the refuse away from the ship because the elevation of the dock is generally too high above the entrance to the ship's storage areas for easy waste transfer. The refuse can be loaded onto the barge manually, by forklift, or by winch. If the refuse from the barge is not discarded at sea, a conventional waste collection truck may be placed on the barge to receive the wastes.

Forklifts that are used to move supplies inside the ships are also used to unload refuse when the material is appropriately contained.

On-shore waste disposal is usually expensive compared with overboard discharge. The cost of unloading and disposing of solid waste from a cruise ship at dockside can exceed $2,000. Therefore, the incentive for decreasing the amount of waste disposed of in this manner is generally high. However, some ports do not charge extra for waste disposal. Instead, the waste disposal fee is included in docking fees.

In response to regulatory pressure, waste management aboard cruise and Navy ships is gradually becoming more sophisticated, as it is on land. Many new vessels have been constructed with pulping systems, incinerators, or both. Incinerator design has improved to the point that combustion systems now include energy recovery equipment.

Small Craft

Small ferries, pleasure and coastal fishing boats also generate solid waste that may be disposed of at sea. Although the solid waste volume generated on board each individual craft is small, the plastic waste portion is estimated to be much higher than on Navy and cruise ships.

Typically, small craft are engaged in relatively brief trips in coastal waters. On short trips of up to a few days, solid waste can be stored aboard a vessel and unloaded at dockside. Marinas and small ports provide refuse containers at dockside, generally at no additional charge to small quantity waste generators. The waste disposal costs are usually supported by docking fees.

Sorting studies performed on solid waste collected at commercial moorages and recreational marinas have indicated that waste from small craft that is returned to port does contain a relatively high proportion of plastic. However, since small craft typically ply coastal and inland waters in which most countries forbid the disposal of waste, the amount of waste disposed at sea by small craft is unknown.

Freight Vessels

The final category of vessel includes freighters, bulk cargo ships, tankers, and container and automobile carriers. The typical crew size on ocean freighters is from 15 to 40. Typically, all solid waste is thrown overboard in international waters. The waste generated in territorial waters is retained until it can either be off-loaded into refuse containers in port or discharged overboard when the ship next reaches international waters.

Very little useful information is available regarding waste generation rates and waste composition from freight vessels. Although some studies have attempted to project the amount and types of waste discharged at sea, there is no evidence in the literature that waste generation rates and composition have been measured by sampling.

In order to obtain a rough estimate of the waste generation rates and waste composition for freight vessels, we informally surveyed several U.S.-flag carriers and some U.S. companies that own or manage vessels operated under flags of convenience. Typical waste generation rates were estimated at approximately 1 yd^3/day. The typical waste composition is estimated to be as follows:

Item	Percentage of Waste Stream
Garbage (biodegradable)	60
Engine Room Wastes	25
Glass Bottles	2
Cardboard	10
Aluminum Cans	0.5
Miscellanous (includes plastic)	2.5
TOTAL	100.0

Using appropriate density factors, this survey indicated a waste generation rate of 3 to 4 lb/person/day. The low proportion of plastic reported (< 2.5%) reflects reported provisioning changes made to date in response to ratification of MARPOL Annex V. A number of U.S.-flag carriers report that they have already instructed their steward departments to discontinue the purchasing and use of styrofoam cups, plastic garbage can liners and plastic food storage bags. Where possible, stewards have been instructed to purchase food packaged in non-plastic containers.

Many of the newer cargo vessels are equipped with incinerators to dispose of the dry, combustible portion of the waste stream, including plastics. While incinerators have been installed on ships for this purpose for many years, previous designs required more labor to operate and maintain the devices than did overboard discharge of wastes. Consequently, the devices were not commonly used.

OPTIONS FOR WASTE PLASTIC DISPOSAL

With the implementation of MARPOL Annex V, the international agreement to prohibit discharge of plastics into marine waters, most of the world's fleet will legally be required to change the way in which waste plastic is disposed. Practical options for the disposal of waste plastic vary with the vessel type and use; however, most operators of oceangoing vessels will most likely choose from the following:

1) incineration of waste plastics aboard ship, either alone or mixed with other waste materials, such as paper;

2 treatment and storage of the entire waste stream for unloading at port (practical for short voyages only); or

3) source separation of waste plastic, treatment for storage, and unloading at port.

In the absence of air-emission regulations for incinerators operating on oceangoing vessels, many vessel operators are likely to incinerate plastics at sea rather than separate and store plastics for disposal or recycling on shore. Without air-emission standards, incinerators installed on ships may be crude, in effect converting plastic pollution of the oceans into an air pollution problem. However, recycling could provide an alternative to land-based disposal of eligible plastics (those plastics that have not been in contact with foreign foodstuffs or waste from foodstuffs) for those vessel operators electing to source separate waste plastic, since waste plastics unloaded from vessels in port could be used to feed either mono- polymer or mixed polymer plastic reprocessing systems.

Given that plastic may not be disposed of at sea, the principal obstacles to recycling the portion of plastic wastes generated on oceangoing vessels that have come into contact with food wastes are government regulations for the treatment of foreign wastes. The U.S. Department of Agriculture (USDA) is responsible for enforcement of these regulations in U.S. ports. The Canadian government and other governments have similar regulations. Strict quarantine and sterilization requirements for wastes generated from materials of foreign origin can greatly complicate the offloading of shipboard recyclables. To date, the USDA has considered some alternatives to its strict sterilization and disposal regulations. Consideration of alternatives has been initiated because of the high costs of foreign refuse sterilization and the current interest in limiting plastic waste disposal at sea.

Once food-contaminated plastic is thermally sterilized according to USDA requirements, it could serve as a feedstock for mixed or monopolymer reprocessing systems if the USDA's landfilling requirement could be relaxed. An effective sterilization technique could contribute to the feasibility of recycling contaminated waste plastic, however, the current thermal sterilization process may cause some physical property degradation of polymers with low softening temperatures. If thermal damage to the polymers is significant, alternative sterilization procedures could be explored. For example, one approach might be to develop washing systems that effectively sterilize the waste plastic feedstock before processing.

Waste plastic generated aboard U.S. vessels that do not visit foreign ports or contact foreign vessels are not subject to the requirements for the thermal sterilization of waste and therefore the diminution of physical properties that can accompany thermal sterilization. Fishing vessels comprise a large portion of U.S. shipping vessels that do not contact foreign ports or foreign ships. At the same time, fishing vessels also are substantial generators of polymers in relatively pure form. Polyethylene and polyamide are examples. If these plastic wastes can be segregated aboard ship, they would be attractive feedstock for land-based plastic recycling programs. Mixtures of waste polymers would also be recyclable at certain land-based locations. However, the markets for mixed plastics are less developed and exist only in certain locations in the U.S.

The enactment of the Recycling Act of 1988 (April 26, 1988) should assist and stimulate the recycling of plastics. Portions of the Act address the technical, institutional, marketing, and environmental aspects of waste plastics. The level of activities authorized by the Act are substantial and if conducted successfully should result in facilitating the recycling of plastics generated aboard ships and onshore. A copy of the Act is included in this report as Appendix B.

Section 5

REFERENCES

1. Society of The Plastics Industry, Facts and Figures, Washington D.C., 1985.

2. U.S. Environmental Protection Agency, Resource Recovery and Waste Reduction, fourth report to Congress, EPA SW-600, 1977.

3. Pearson, W., "Plastics Recycling in the United States," in Plastics Recycling as a Future Business Opportunity, proceedings of the Recyclingplas II conference, June 1987, Technomic Publishing Co., Inc., PA, 1988.

4. Cal Recovery Systems, Inc., North Santa Clara County Comprehensive Waste Characterization Study, CRS Report No. 83-10, January 1984.

5. Cal Recovery Systems, Inc., Composition and Properties of Municipal Solid Waste and Its Components, prepared for the U.S. Department of Energy, Contract No. DE-AC03-83SF11724, May 1984.

6. Cal Recovery Systems, Inc., Broward County Resource Recovery Project -- Waste Characterization Study, Report No. 87-4, February 1988.

7. "Background Memorandum," Hearing on H.R. 940, the Plastic Pollution Research and Control Act, U.S. House of Representatives, Subcommittee on Fisheries and Wildlife Conservation and the Environment, June 10, 1987.

8. Curlee, T.R., The Economic Feasibility of Recycling -- A Case Study of Plastic Wastes, Praeger, 1986.

9. Center for Environmental Education, Plastics in the Ocean: More than a Litter Problem, Washington, D.C., February 1987.

10. Weisskopf, M., "Plastic Reaps a Grim Harvest in the Oceans of the World," Smithsonian, Vol. 18, No. 12, March 1988.

11. Gerrodette, T., Choy, B.K., and Hiruki, L.M., An Experimental Study of Derelict Gill Nets in the Central Pacific Ocean, Southwest Fisheries Center Administrative Report H-87-18, Honolulu Laboratory, November 1987.

12. Andrady, A.L., Research on the Use of Degradable Fishing Gear and Packaging Materials, Northwest Fisheries Center Processed Report 87--03, January 1987.

13. Deanin, R.D, A. Amran, R. Saraogi, and N. Matani, "Recycle of Polystyrene," Polymer Preprints, 24(2), pp. 430-1, 1983.

14. Sekiguchi, Y., T. Kuroki, T. Sawaguchi, and T. Ikemure, "Studies on the Thermal Degradation of Synthetic Polymers," Journal of the Chemical Society of Japan, p. 1220, 1977.

15. Ide, S., T. Ogawa, T. Kuroki, and T. Ikemura, "Conrtolled Degradation of Polystyrene," Journal of Applied Polymer Science, 29, pp. 2561-71, 1984.

16. Trezek, G.J., and Tixier, J., "Processing PET Bottles into High Purity Flake," Resources and Conservation, 15, pp. 151, 1987.

17. Rodriguez, F., Principles of Polymer Systems, 2nd Edition, McGraw Hill, NY, p. 449, p. 436, 1982.

18. Sittig, M., Organic and Polymer Waste Reclaiming Encyclopedia, Noyes Data Corp., NJ, 1981.

19. Mandoki, J.W., "Depolymerization of Condensation Polymers," U.S. Patent 4,605,762; August 12, 1986.

20. Monet, G.P., "Adipic Acid from Nylon Waste," U.S. Patent 3,069,465; December 12, 1962.

21. Datye, K.V., Raje, H.M., and Sharma, N.D., "Poly(ethylene Terephthalate) Waste and its Utilization: A Review," Resources and Conservation, Vol 11, No. 2, p. 117, 1984.

22. Brewer, G., "European Plastics Recycling Part II," Resource Recycling, p. 16, July 1987.

23. Brewer, G., "European Plastics Recycling Part I," Resource Recycling, May/June, 1987

24. Maczko, J., "A System to Mold Mixed Contaminated Plastics into Wood, Metal, and Concrete Replacements," Plastics Recycling as a Future Business Opportunity, proceedings of the Recyclingplas II conference, June 1987, Technomic Publishing Co., Inc., PA, 1988.

25. Fornasero, F., Recovery of Heterogeneous Plastic Materials from Rejects and Rubbish: Revive System Cadauuta S.a.S.-10020 San Sebastiano da Po (To), Italy. EEC Contract RUW-074-I(S)., 1986/87.

26. New, R., Plastics Waste Recycling in the United Kingdom, Department of Trade and Industry, Recycling Advisory Unit, Warren Spring Laboratory, April 1986.

27. Plastic Waste Mangement Institute, Plastic Waste: Resource Recovery and Recyling in Japan, Fukide Bldg. 1-13, 4 chome, Toranomon, Minakato-ku, Tokyo, Japan. Paperback 193 pp. plus an insert of 12 pages of updated tables and figures, 1985.

28. Polymer Technologies Limited, A Study of the Plastics Recycling Industry, England.

29. Bukens, A.G., "Some Observations on the Recycling of Plastic and Rubber," Resource Recovery Guide, Van Nostrand Reinhold, NY, 1983.

30. Basta, N., "Plastics Recycling Grows Up," Chemical Engineering, p. 22, November 23, 1987.

31. Plastic Bottle Institute, Plastic Bottle Recycling Directory and Reference Guide 1987, Washington, D.C.

32. Milgram, J., "Polyethylene Terephthalate (PET) Bottles: Status Report," Plastics Recycling as a Future Business Opportunity, proceedings of the Recyclingplas II conference, June 1987, Technomic Publishing Co., Inc., PA, 1988.

33. Glenn, J., "St. Jude and the Plastic PET," BioCycle, p. 38, August 1987.

34. Adams, J.C., Ed., Center for Plastics Recycling Research, N.J., Report, Vol. 2, No. 2, December 1987.

35. The Plastic Bottle Institute, Plastic Bottle Recycling 1986, (SPI), NY, 1986.

36. Bennett, R.A., PET Recycling: "Today's Plastic Soda Bottle Fills Tomorrow's Ski Jacket," Waste Age, January 1985.

37. Stevens, A., "Dairy Bottle Recycling," Plastics Recycling as a Future Business Opportunity, Proceedings of the Recyclingplas II conference, June 1987, Technomic Publishing Co., Inc., PA, 1988.

38. Brewer, G., State Planning for Post-Consumer Plastics Recycling, Report presented at North American Recycling '87, Chicago, IL, May 28, 1987.

39. The British Plastics Federation, Report on the Conclusion of the BPF PET-A-Box Project, 1986

40. Volger, J., "Plastics Recycling in the Third World," Resource Recycling, Volume 6, No. 7, January/February, 1988

41. Brewer, G., "European Plastics Recycling, Part III," Resource Recycling, September/October, 1987.

42. Norsk Hydro Environmental and Energy Systems, "Cruise Ship Garbage Disposal -- State of the Art," Oslo, Norway, 1987.

43. Personal communication with Mr. William A. Mitchell (formerly with Holland America Westours, Seattle, WA), May 18, 1988.

Appendix A

REVIEW OF ACTING AND PENDING RECYCLING REGULATIONS

INTRODUCTION

In recent years, a considerable amount of legislation has been introduced, primarily at the state level, that addresses the problem of plastic disposal and recycling. This appendix presents a detailed review of domestic statutes and regulations that affect the recycling of waste plastics. The review discusses acting and pending statutes and groups them according to the approach by which they affect recycling: 1) waste reduction techniques; 2) strategies to increase the supply of recycled materials; and 3) strategies to increase the demand for recycled products.

This material was collected in January 1988. The pace of environmental legislation is increasing and a considerable amount of additional legislation is expected during the next several years.

Waste Reduction Techniques and Attempts to Address the Issues

Statutory Bans on Plastics --
Among the regulatory strategies proposed most frequently by lawmakers is the statutory ban or restriction on the sale or use of plastic products. Many of the bills that address the issue of plastic wastes place a straightforward restriction on what would usually be free market activity.

Included in this discussion will be bans on styrofoam containers made with chlorofluorocarbons, plastic milk jugs and shopping bags, nonbiodegradable plastic six-pack rings, and all plastic packaging. These types of methods have as their target products already on the market.

In addition, there have been bills proposed in states such as Kentucky that contemplated restricting the introduction of a new product onto the market; for example, the plastic can.

Representatives of the plastics and packaging industries have vehemently opposed such proposed bans, often times with much success. These entities criticize such regulatory schemes as being inappropriate or ineffective interference in the "free market."

This section on statutory bans will focus on the usage of CFC-containing styrofoam containers, then turn to the issue of plastic six-pack rings and, finally, discuss packaging law and plastic milk containers.

PROHIBITION OF USE OF FOAM FOOD CONTAINERS MADE WITH CFCs

City of Berkeley, California

This city recently enacted an ordinance that bans the use by fast food outlets and markets of foam plastic food containers made with chlorofluorocarbons (CFCs). By its action on September 23, 1987, the City of Berkeley became the first in the nation to place restraints on the use of CFC-containing plastics. The ban, which took effect February 1, 1988, applies to the 400 fast-food restaurants and mini-markets.

Role of CFSs in the Destruction of the Ozone Layer--
CFCs are released during the manufacturing process into the atmosphere and there is some evidence that they attack the ozone layer. CFCs are chemical foaming agents that give certain plastics a very low bulk density and a high insulating value.

Ozone shields the Earth from dangerous levels of ultraviolet rays that cause skin cancer. Recent reports by federal agencies have documented reduction of ozone levels by 5%-7% worldwide. Medical experts have witnessed a large increase in the rate of skin cancer.

CFCs are used in a number of applications, including refrigeration, mobile air conditioning, and plastic foams. The use as a propellant was banned in the U.S. in 1978 because of its potentially hazardous effects.

Berkeley directed its Solid Waste Management Commission in May 1986 to research the issue of excess litter near mini-markets. On May 5, 1987, the SWMC presented several recommendations on plastic packaging and biodegradable litter to the Council.

The Commission made recommendations that can be grouped into three major subject areas:

Set 1--Regarding the Use of Chlorofluorocarbons in Packaging

Set 2--Regarding Food Service Packaging

Set 3--Regarding Education and Recycling

Discussion of the Recommendations and their Bases

Set 1 (Chlorofluorocarbons in Packaging) Recommendations:

1A.) The City of Berkeley should enact legislation prohibiting Berkeley merchants from adding or supplying, to any product sold within the City, polystyrene (PS) foam packaging or disposables that utilize Chlorofluorocarbons (CFCs) in manufacture.

Legislation should include provisions that require merchants to obtain legally enforceable signed statements from their suppliers verifying that PS foam packaging did not utilize CFC in manufacture. Merchants should retain such statements for a period of one (1) year.

Legislation should also contain a "sunset" provision to automatically terminate the ordinance should CFC use for PS foam manufacture be banned at a state or federal level.

1B.) The city of Berkeley should adopt a policy that the City and its various agencies will not purchase any PS foam product that utilizes CFC in manufacture.

Set 2 (Food Service Packaging) Recommendations:

2A.) The City Council should adopt a resolution that encourages Berkeley merchants to establish a voluntary reduction program to attain the following objectives:

1. Reduce by 50% the current use of non-biodegradable packaging (not otherwise exempted) by each food service vendor;

2. Significantly reduce food-related litter; and

3. Reduce the total amount of packaging used when possible.

Such a program is to be planned, financed and administered by Berkeley merchants.

2B.) The City Council should adopt an ordinance requiring all packaging added to, or supplied by merchants within the City of Berkeley, for foods and beverages sold for immediate consumption off vendor's premises, to be biodegradable, with an effective date of February 1, 1990.

Set 3 (Education and Recycling) Recommendations:

3A.) The City should work with the Berkeley Chamber of Commerce and other business and service organizations to educate members and consumers to:

1. The environmental impacts of CFC use;
2. Environmental concerns of non-biodegradable packaging;
3. Benefits of reducing the amount of packaging when possible;
4. Benefits of commercial recycling;
5. The need for litter control; and
6. The principle of "Reduce - Reuse - Recycle".

3b.) That the above be included within the scope of the educational programs outlined in the 1986 Solid Waste Management Plan.

<u>Discussion of the Actual Ordinance</u>

The Ordinance states in Section 3 that:

"No takeout food vendor shall purchase, obtain, keep, sell, distribute, provide to customers, or otherwise use in its business, any CFC-processed takeout food packaging,..."

There are two areas of exemptions to Section 3 which are found in Section 6 and 7. Section 6 states that the "Council may exempt an item or type of packaging from the requirements of this Ordinance, upon a showing that the item or type has no acceptable non-CFC-processed equivalent and that imposing the requirements on that item or type would cause undue hardship."

Section 7 goes on to exempt "Takeout food packaging required to be purchased under a contract entered into prior to March 31, 1987..."

A "takeout food vendor" is defined by the Ordinance as "any restaurant or other establishment selling food and beverages for immediate consumption located within the City...which receives more than 20% of its revenues from the sale of takeout food." As noted, this covers more than 400 fast-food restaurants and mini-markets in Berkeley.

The takeout food vendor is given the responsibility of obtaining "from each of its suppliers a written statement signed by the supplier,... stating that the supplier will supply no CFC-processed takeout food packaging..." (Section 4A).

The supplier must also "note on each invoice for takeout food packaging supplied to the vendor that the packaging covered by the invoice is not CFC-processed", (Section 4A) and also note the manufacturer of the packaging.

The Ordinance goes on to require that all contracts between a vendor and supplier shall include a provision that the supplier will supply no CFC-processed packaging, as well as a provision stating that each invoice for such packaging supplied is not CFC-processed and the identity of the manufacturer of the packaging. (Section 4B)

These provisions clearly make it the responsibility of the vendor to request an enforceable written promise from the supplier, thereby forcing the supplier to communicate with the manufacturer of the packaging regarding its chemical processing.

The Ordinance makes it unlawful for any supplier to make any misstatement of material fact to any takeout food vendor or to the City regarding the use or non-use of CFCs in the manufacture of any takeout food packaging supplied. (Section 4C)

The City of Berkeley is prohibited by the Ordinance from purchasing any CFC-processed takeout food packaging, and from utilizing such packaging at any City-sponsored event. (Section 8)

The Ordinance is made void by the enactment or adoption of any law or regulation by the federal government restricting the use of CFCs as blowing agents in the manufacture of plastic foams. (Section 12)

<u>Consideration of a Total Ban on Plastics by Berkeley</u>

The City of Berkeley also considered an ordinance which totally banned plastic fast-food containers. This law was also recommended to the council by the Solid Waste Management Commission. The Council decided against the total ban, but their action has kept the issue alive. The Council instead voted to send the law back to the Commission for re-drafting.

This move would allow the Council to reconsider the law again before the end of 1987. If approved, the law would have banned the use of all plastic food containers by the beginning of 1990. The ban on plastic and other non-biodegradable containers would only have taken effect if efforts to persuade merchants to voluntarily give them up fail. The Council reportedly was considering a modification of the ban to allow takeout vendors to use aluminum foil or other materials that can be recycled.

Vermont Law

In June, 1987, Governor Kunin of Vermont signed into law H.B. 196. The law, among other things, calls for the preparation of a State Solid Waste Management Plan to be in place by April 30, 1988. The legislature has mandated that the plan be formatted on the following set of priorities: waste reduction, reuse and recycling, waste volume reduction, and land disposal of residues. The law also contemplates direct ban on products and packaging.

Section 6604 (c)(1) states that the secretary of the agency of environmental conservation shall consider ways to keep "...non-recyclable, non-biodegradable material out of the waste stream..." The secretary shall give immediate consideration to the following:

" (B) evaluation of polystyrene packaging, particularly that used to package fast food on the premises where food is sold, ...

" (D) identification of unnecessary packaging, which is non-recyclable and non-biodegradable.

In Section 6604 (c)(2) the secretary is ordered to consider

"(A) product and packaging bans, products or packaging which ought to be exempt from such bans, the existence of less burdensome alternatives, and alternative ways that a ban may be imposed,

"(B) tax incentives, including the following options:

(i) product taxes, based on a sliding scale, according to the degree of undue harm caused by the product, the existence of less harmful alternatives, and other relevant factors,

(ii) taxes on all non-recyclable, non-biodegradable products or packaging,

(C) deposit and return legislation for certain products."

Suffolk County, New York

Officials in Suffolk County have considered a ban on the use of specific types on nonbiodegradable plastic packaging, particularly fast food containers. The bill would prohibit not only fast food restaurants from using plastic or other nonbiodegradable containers, but also prohibit stores from using plastic bags for customer's purchases. Thus, the ban would affect the use of nonbiodegradable packaging at the retail level, and not the wholesalers.

BAN ON PLASTIC SIX-PACK RING CONTAINER HOLDERS

California

The state of California has recently amended its Health and Safety Code Section 24384.5 regarding the use of plastic rings for connecting beverages. The amended statute provides that

> "...one year after the determination by the California Waste Management Board that degradable plastic connectors are commercially available, no beverage shall be sold or offered for sale at retail in this state in beverage containers connected to each other with plastic rings or similar devices which are not classified by the board as degradable..." (Section 24384.5 (a))

The statute goes on to state that "degradable" shall mean all of the following:

"Degradation by biologic processes, chemodegradation, or degradation by other natural degrading processes." (Section 24384.5 (b)(1))

A violation of these prohibitions is made an infraction and a new crime by the statute at Section 24384.5(d).

Vermont

The state of Vermont has adopted a law which prohibits the use of nonbiodegradable plastic rings. Title 10, Chapter 53, Section 1525 of the Vermont Statutes Annotated states:

> "(a) No beverage shall be sold or offered for sale at retail in this state:
>
> > "...(2) in containers connected to each other with plastic rings or similar devices which are not classified as biodegradable by the secretary."

Wisconsin

The Wisconsin State Legislature passed a bill in late October 1987 which prohibits detachable metal rings on beverage containers and non-biodegradable or nonphotodegradable plastic ring connectors. The bill is also known as AB 243.

The statute states that "degradable" shall mean the following:

> (2) "Degradation at a rate which is equal to, or greater than, the degradation by a process specified in paragraph (1) of other commercially available plastic devices;"
>
> and
>
> (3) "Degradation, which, as determined by the board, will not produce or result in a residue or byproduct which, during or after such process of degrading, would be a hazardous or extremely hazardous waste identified pursuant to Chapter 6.5 (commencing with Section 25100) of Division 20."

Thus, manufacturers are permitted to produce plastic rings which undergo degradation by processes other than those listed, as long as the professionals, and affected environmental groups, shall conduct a review of existing studies, literature, and data regarding pollution of the marine and land environment resulting from accumulations of nonbiodegradable debris, with an emphasis on plastics and styrofoam.

There is also a bill (SB 88) pending before the Wisconsin Legislature that bans any detachable components of beverage containers. This could conceivably cover plastic detachable parts.

Oregon

The Oregon Liquor Control Commission administers various aspects of Oregon's Bottle Bill. One part of the Bottle Bill requires that:

> "No person shall sell or offer for sale at retail in this state metal beverage containers connected to each other by a separate holding device constructed of plastic rings or other material which will not decompose by photobiodegradation, chemical degradation, or biodegradation within 120 days of disposal." (ORS 459.850(5))

It appears that this statute as written does not apply to non-metal containers; therefore if there are other types of containers such as glass, or plastic, or some combination of materials besides metal, then these containers may be exempt from the statutory requirement. This loophole would diminish the effectiveness of the policy behind degradable plastic rings.

The Commission was asked to study whether the plastic rings used in Oregon comply with the 120-day deadline for decomposition. Their findings included the following: the ring used in Oregon is, for the vast majority of time, a photodegradable one (the Hi-Cone ECO ring); rings placed in a sunny, unobstructed area in the spring and summer will probably decompose within the 120 days; rings placed out in late summer or winter will probably decompose sometime around the 120-day limit; rings discarded in fall probably do not decompose until after the 120-day limit; and rings covered by leaves, snow, or sand will probably not meet the 120-day limit.

BAN ON PLASTIC MILK CONTAINERS

Minnesota

Minnesota has in place a packaging review and control law that the state supreme court upheld after six year of concerted challenges. This court, however, concluded that the regulations were merely advisory and did not have the force or effect of law. Instead, judging that the law and its guidelines would be too impractical to carry, too costly, too broad, too confusing, and too burdensome, Minnesota opted to pursue a recycling strategy.

In a related decision, the Minnesota court struck down the 1977 Legislature's attempted ban of non-refillable plastic milk bottles. The ban was sustained by the U.S. Supreme Court in 1981, but has not been enforced.

There is in Minnesota a law entitled "The Recycling of Solid Waste Act," passed in 1973, with the stated purpose of preventing containers that " would constitute a solid waste disposal problem or be inconsistent with state environmental policies."

The Minnesota Pollution Control Agency (MPCA) was charged with devising a system for reviewing the environmental impact of new or revised packages introduced into the state. This mandate included development of education programs for the public and advice and assistance programs for industry.

Following review and a hearing, MPCA can ban the sale of products in the proposed packaging. If a package is banned, the Legislature must affirm the ban in the next session or the packaging stands approved. MPCA has only 120 days to respond to any packaging changes.

The criteria given MPCA to work under are to: "encourage those packaging alternatives which:

1. Minimize the potential for environmental contamination, including but not limited to the release of metals or substances with the potential for biological harm (the potential of winding up as litter was a consideration);

2. Minimize the total system energy costs (these include mining, manufacturing, fabrication, transportation, and disposal);

3. Minimize the use of scarce or non-renewable resources (landfill volume being one consideration);

4. Minimize the use of virgin materials;

5. Minimize adverse economic effects on the consumer, the labor force, and industry, consistent with (1) and (2) above;

6. Are most recyclable where recyclability is consistent with (1) and (2) above." (?)

The regulations required MPCA to compare new packaging forms with "existing package/containers(s) and/or all feasible alternatives" to determine how the new forms rate in terms of meeting the above criteria. The law does not apply to changes in packaging color, size, printing or shape -- only to alterations in the composition of the package or the kind of material it contains.

It also does not apply to bulk packaging; to containers marketed with a deposit of 5 cents or more; to meat packaging; or to specified densities or coatings for packages made substantially of glass, aluminum, steel, paper or plastic.

In order to limit the regulations to high volume packaging forms, MPCA set forth regulations limited to food and beverage packaging, household and cleaning supplies, and cosmetics and toiletries.

The MPCA has the authority to review and ban packages but does not do so. Minnesota has instead chosen to address its solid waste management problems with a statewide recycling effort. Cities and counties participate in mandatory planning, loan and grant programs, and projects that use handicapped citizens to collect and sort recyclable materials.

WASTE ABATEMENT PROGRAMS AND CONCOMITANT LEGISLATION

There is another category of legislation implemented in the United States which in essence functions as a system to recycle plastic. This area of environmental management is known as waste abatement or reduction.

Iowa

The state of Iowa has recently passed legislation known as the Groundwater Protection Act (the Act). Within the Act is a section entitled "Waste Abatement Program." The Act was passed in the spring of 1987 and took effect July 1, 1987.

It is the responsibility of the Iowa Department of Natural Resources to enforce the Act, and it seems as if the power of the abatement section is unrealized to date. It appears, though, that this section could have nationwide significance for the future of recycling and waste reduction.

The text of the section on waste abatement, carrying the possibility of major ramifications, states:

> "If the department receives a complaint that certain products or packaging which when disposed of are incompatible with an alternative method of managing solid waste and with the solid waste management policy, the director (of natural resources) shall investigate the complaint. If the director determines that the complaint is well-founded, the department shall inform

the manufacturer of the product or packaging and attempt to resolve the matter by informal negotiations.

"If informal procedures fail to result in resolution of the matter, the director shall hold a hearing between the affected parties. Following the hearing, if it is determined that removal of the product or packaging is critical to the utilization of the alternative method of disposing of solid waste, the director shall issue an order setting out the requirements for an abatement plan to be prepared by the manufacturer within the time frame established in the order.

"If an acceptable plan is not prepared, the plan is not implemented, or the problem otherwise continues unabated, the attorney general shall take actions authorized by law to secure compliance."

The intent of the legislators reportedly was to address any possible problems that might result if a product or packaging caused a new method of solid waste disposal to be ineffective. One aim of the law is to provide a means for working out problems that might occur with the advent of new disposal technologies; another is to encourage new technologies that will deal with solid waste without polluting groundwater.

The wording of the section could well allow broad applications. For example, if a product or packaging is simply not recyclable, it appears that it may be covered by the law. This could occur because recycling most certainly qualifies as an "alternative method of managing waste," as required by the Act.

This interpretation of the statutory language is harmonious with the priorities set out elsewhere in the Act. These priorities of Iowa's solid waste management policy are stated to be: " volume reduction at the source" and "recycling and reuse".

Thus, the waste abatement law can be seen as primarily a tool to prevent a product, such as plastic or packaging manufactured with plastic, from directly interfering with the recycling process. It is conceivable that the law could be used by the Department of Natural Resources if it receives complaints about excessive litter and waste from fast food operations.

The original version of the Iowa law gave the state the ability to force a company to "cease and desist" the sale of a product or packaging. Manufacturers objected so strongly to this that the result was softer wording which emphasized that the manufacturer and the state would work together to solve the problem.

<u>Nebraska</u>

Nebraska has recently addressed the issue of waste abatement in a law that was included in an unsuccessful bill dealing with solid waste management.

One clause in the defeated bill proposed that if a manufacturer or trade group representing manufacturers of a product or packaging failed to agree to the state's waste abatement plan, manufacturers would have to pay an annual licensing fee of $5,000 to sell the product in Nebraska.

The law was supported by state recycling associations as it encourages manufacturers to take responsibility for everything they make. The bill would not be able to force a company to take a product off the shelf, but could give the state authority to draw the manufacturer into a discussion about the environmental and economic cost to the state.

For example, if a beverage company began using containers with a mix of aluminum and plastic, the law would have allowed the state to enter into a dialogue with the manufacturer very early regarding the recyclability of the container.

This type of authority could be instrumental in dealing with the introduction of the plastic can, such as the one marketed by Petainer Development Co. of Atlanta, onto the shelves of Nebraska grocery stores. Parenthetically, the plastic can, as produced by Petainer, is essentially the same size as a 12-ounce aluminum can, with the base of the can made of plastic, and topped off with a conventional aluminum lid.

The Nebraska Legislature as of October, 1987, is conducting a study on the waste abatement program and other solid waste management proposals.

Connecticut

The State of Connecticut passed "An Act Mandating Recycling in Municipalities" in June, 1987. The act states that by January 1, 1991, no recyclables will be allowed into landfills or waste-to-energy facilities.

The Department of Environmental Protection has defined the word "recyclables" for the purpose of the act. By February 1988, the Department's Commissioner will adopt regulations designating items to be recycled.

Municipalities will then have nine months to revise their solid waste management plans to incorporate recycling or file a recycling plan. If the municipalities have not complied with these regulations on or after January 1, 1989, the Commissioner can order their participation in a regional recycling program.

Vermont

In June of 1987, the Governor of Vermont signed H.B. 196 into law. This bill was discussed earlier in this report (See section on statutory bans). The law provides for the implementation of a Waste Management Plan, which is to be adopted by April 30, 1988.

A section of this law contains language proving it to be a vehicle for waste abatement. Section 6604 (a)(1) states that the plan shall be based upon the following priorities, in descending order:

"(A) the greatest feasible reduction in the amount of waste generated;

(B) reuse and recycling of waste to reduce to the greatest extent feasible the volume remaining for processing and disposal;

(C) waste processing to reduce the volume necessary for disposal;

(D) land disposal of the residuals."

Oregon

The state legislature in Oregon passed a waste reduction and waste management law in its 1987 session which could have an effect on the presence of plastics in the environment and recycling efforts.

The bill, HB 2619, prohibits regional disposal sites from accepting waste from inside or outside the state unless the Oregon Department of Environmental Quality certifies that the governmental unit from which the waste comes has implemented the opportunity to recycle as required by Oregon law.

California

A bill which could have major ramifications on the plastics recycling efforts in the state of California is SB 52, presently under consideration by the Legislature. It is authored by a state senator opposed to a waste-to-energy facility in his district.

The requirements of this bill are numerous. One section which would effect plastics in the waste stream would require every county to prepare a solid waste composition study for inclusion in the next revision of the county's solid waste management plan. Under California law, the cities and county must agree on a new plan every three years.

This proposed provision would specify that the waste composition study must be submitted to the local enforcement agency (the local health authority which issues facility permits) and the state Department of Conservation.

Second, the bill would prohibit the issuance to any solid waste incineration facility of a solid waste facility permit by the enforcement agency or a permit by the air pollution control district prior to completion of a solid waste composition study by every county within the wasteshed of the facility.

Of particular importance to the reuse of plastics is a provision which would prohibit any permit from authorizing a facility to incinerate more than 50% of the solid waste generated within the wasteshed.

The bill would require every new waste-to-energy facility to remove substantially all of specified recyclable materials (including plastic) prior to incineration. Furthermore, SB 52 which would require the enforcement agency to ensure that at least 35%, by weight, of solid waste in the waste stream be removed for reuse or recycling.

Regarding the composition study mandated by the bill, Govt. Code Section 66796.91 states:

> "The solid waste composition study shall be conducted in a scientifically sound manner and shall include, but not be limited to, all of the following:
>
> (a) An inventory of wastestream materials taken from field samples of solid waste.
>
> (b) The quantities, expressed in both weight and volume by categories of newsprint; glass; ferrous metals; nonferrous metals; corrugated cardboard; plastics; mixed waste paper; compostable materials..."

The section restricting incineration states:

> "No permit shall authorize the incineration of more than 50 percent of the solid waste generated within the wasteshed of any solid waste incineration facility. Every permit shall require that substantially all of the following materials be removed for reuse or recycling form the wastestream prior to incineration:
>
> (a) Ferrous metals
> (b) Aluminum cans
> (c) Glass
> (d) Nonferrous metals
> (e) Plastic
> (f) Newspaper
> (g) Corrugated cardboard
> (h) Office paper
> (i) Any other materials which can be removed through cost-effective recycling" (Govt. Code Section 66796.94)

Another provision of the proposed law dealing with the volume of the wastestream to be removed for reuse and recycling adds:

> "The enforcement agency shall require that at least 35 percent, by weight, of the solid waste in the wastestream of any solid waste incineration facility, as determined in accordance with the most recent solid waste composition study, shall be removed for reuse or recycling. Every enforcement agency shall take measures to protect the confidentiality of any proprietary information obtained in this regard." (Govt. Code Section 66796.94)

Ultimately, these sections of law would result in higher amounts of plastics being removed and recovered from the wastestream. By setting a mandatory, and specific percentage of plastic to be extracted before incineration of any waste, this bill would act to conserve plastic resources.

FINANCIAL INCENTIVES AND DISINCENTIVES: USE OF TAXES AND TAX CREDITS

New York State

Tax Levied on Each Container--

In the state of New York this year, there have been bills introduced which would impose a tax on containers. The companion bills, AB 6804 and SB 5732, propose a tax of three cents per container which would be used to encourage packaging made from recycled materials and promote reusable and easily recycled packaging. Thus, the bills would impose a packaging tax based upon three factors:

- recyclability,
- reusability, and
- recycled content.

Manufacturers would get back a penny if they used recycled materials, another penny if the packaging could be recycled, and all three cents if both criteria were met.

New Jersey Tax Credit Allowance

In the New Jersey Statewide Mandatory Source Separation and Recycling Act of 1987, there is a provision for receiving a 50% tax credit against their State Corporate Business Tax for industries purchasing new recycling equipment. The equipment must be certified by the Department of Environmental Protection as eligible for the credit.

The tax credit may not reduce a business' tax liability by more than 50%. The tax credit must be taken for a minimum of 5 years, but may be carried forward until the 50% credit is fully claimed.

Wisconsin Tax Credit Allowance

There is currently before the Wisconsin State Legislature a bill which would provide a property tax exemption for waste reduction and recycling equipment. The bill, AB 649, would also allow for rapid amortization, depreciation, or first year expensing of the cost of this equipment.

California Recycling Tax Fairness Act

Since 1985, there has been a bill in the California legislature that would have changed the state tax law to treat recycled and virgin materials in the same way.

Under state and federal law, manufacturers receive substantial tax incentives for use of virgin materials, such as the oil depletion allowance, while no tax incentive exists for use of recycled materials.

The present California bill, SB 188, would allow a credit equal to 10% of the amount paid for the recyclable secondary material, purchased on or after October 1, 1987 and prior to January 1, 1993, and recycled within California by the taxpayer.

SB 188 states that it is in the best interests of the state to implement a recycling tax credit for the purpose of increasing the amount of materials recycled by encouraging manufacturers to use recyclable materials in their production processes.

The Franchise Tax Board would be required to prescribe any regulations or rules which may be necessary to carry out the purposes of this section. This bill would add Sections 17053.14 and 23604.6 to the Revenue and Taxation Code.

California's Flat Tax

For a number of years, the California legislature has considered bills which establish a uniform(flat) tax on individuals and corporations. These bills would eliminate all deductions and exemptions. The effect of this would be to put recycled and virgin materials on equal footing for product manufacturers, because neither materials would receive any tax advantage.

Oregon Reclaimed Plastic Tax Credit

Oregon allows an income tax credit for taxpayers who invest in capital assets used to manufacture products made from reclaimed plastic. The credit may be claimed for investments made on or after January 1, 1986, and before January 1, 1989.

Reclaimed plastic means plastic that originates in Oregon from industrial or consumer waste. It must be used to manufacture a plastic product not for medical or food purposes. The reclaimed plastic must be purchased from a plastic recycler other than the person claiming the tax credit. The plastic cannot be reclaimed from the industrial waste generated by the claimant.

Reclaimed plastic product means a plastic product of real economic value. More than 50 percent of the plastic used to make the product must be reclaimed plastic.

Who Can Claim the Credit

Only the owner or contract purchaser of the qualified investment can claim the credit. If the equipment or machinery is leased, the company, corporation or individual claimant must provide a copy of a written agreement between the lessor and lessee designating the party to receive the tax credit.

How the Credit is Figured

The maximum credit allowable in any one year is the lesser of the taxpayer's liability or 10 percent of the certified cost. The total credit available is up to 50 percent of the certified cost of the taxpayer's investment. The total credit is taken equally over 5 years.

The Oregon Department of Revenue has also stated that the taxpayer can claim depreciation or amortization on assets. Credit which exceeds liability may be carried over for the next five years.

Vermont Bill H.B. 196

The state of Vermont has passed a law which contemplates the use of taxes on products and packaging. The secretary of the agency of environmental conservation is given authority, when carrying out the State Solid Waste Plan, to consider tax incentives, including product taxes, "based on a sliding scale, according to the degree of undue harm caused by the product, the existence of less harmful alternatives, and other relevant factors" and "taxes on all non-recyclable, non-biodegradable products or packaging."

Section 6604 (c) (2)(B)(i)-(ii).

SOURCE SEPARATION LAWS

New Jersey

The New Jersey Statewide Mandatory Source Separation and Recycling Act P.L. 1987, c. 102

The state of New Jersey has implemented a source separation and recycling act (the Act) which provides a systematic method for the recycling of plastics. The Act, known as S-1478 and A-1781, was signed into law by the Governor on April 20, 1987.

Of the responsibilities set out by the Act, provisions setting out activities for counties, municipalities and the Department of Environmental Protection (DEP) are directly relevant to this study.

County Responsibilities (p.4, Sec.3 (a) of the Act):

Within 6 months of the effective date of the Act, counties shall prepare and adopt a district recycling plan to include the following:

1. Designate a district recycling coordinator.

2. Identify leaves and at least three other recyclable materials as the designated recyclables in the district.

3. Designate a strategy for the collection, marketing and disposition of source separated recyclable materials in each municipality.

4. The recycling of at least 15% of the prior year's total municipal solid waste stream by the end of the first full year.

5. The recycling of at least 25% of the second preceding year's total municipal solid waste stream by the end of the second full year.

6. Each district recycling plan shall give priority consideration to persons already engaged in the business of recycling.

Six months after DEP approval of the plan, the county solicits proposals for processing and marketing of the materials and enters into contracts or agreements on behalf of the municipalities unless otherwise provided for.

If the county fails to find a market, DEP may grant or deny an exemption for implementation of the plan. If an exemption is denied, DEP must provide assistance to secure markets. Any exemption shall not exceed one year and shall be granted or renewed only upon a finding that the county has made a good faith effort to identify and secure markets.

Any county that has adopted a district recycling plan, which plan has been approved by the DEP prior to January 1, 1987, shall be exempt from the provisions of sections 3 and 4. To be eligible for an exemption, a county shall have established and implemented a countywide mandatory recycling program for at least three materials in addition to leaves, and shall have demonstrated that markets for these materials have been secured.

Each municipality is responsible for the following:

1. Designating a recycling coordinator within 30 days of the effective date of the Act.

2. Providing a collection system within 6 months of the adoption of the county plan.

3. Within 30 days of market agreements, adopting ordinances requiring generators of municipal solid waste to source separate the municipality's designated recyclable materials.

4. Within 30 days of the effective date of the local ordinance, revising their master plan and site plan ordinance to require that proposals for new developments of 50 or more single family units, 25 multifamily units, and 1000 square feet or more of commercial or industrial space incorporate recycling. The Master plan must be updated for recycling every three years and must incorporate a recycling plan element.

5. Publicizing the provisions of the local recycling program at least once every six months.

Portions of the Act which pertains specifically to plastics include the following:

1. No plastic or bimetal beverage container shall be identified as a recyclable container by its labelling unless the DEP determines that a convenient and economically feasible recycling system for that specific container is available.

2. Within 12 months, plastic and bi-metal beverage containers must reach the same recycling rate as glass or aluminum containers, whichever is less. In the event of failure to reach this rate, the DEP submits recommendations for improvement to the Governor and Legislature.

The New Jersey Department of Environmental Protection's Responsibilities:

1. All proposals for solid waste facilities must incorporate the goals of the recycling plans.

2. Determine the recycling rate of plastic and bimetal beverage containers and submit a report to the Governor and the Legislature.

City of Philadelphia

This city has implemented a bill which mandates source separation of recyclables. The bill was signed into law by the Mayor of Philadelphia in June 1987. It requires residents and business operators to separate plastic containers, glass containers, metal cans, newspaper, garbage and yard wastes.

Wisconsin

The state of Wisconsin also has a law regarding the separation of wastes and recycling facilities. The law was created by 1983 Wisconsin Act 426, and became effective in 1986 as Section 144.796.

The section states that:

> "the owner or operator of a solid waste disposal facility which is open to the public shall provide an adequate waste separation and recycling collection facility at the city of the waste disposal facility." (Section 144.796 (1)(a)).

There are two exceptions to this requirement. The first occurs if there already are adequate waste separation and recycling collection facilities in the area. The second exception provides that an " owner or operator of a solid waste disposal facility which receives 50,000 tons or more of solid waste per year" is exempted.

If such separation and recycling facilities do not otherwise exist in a city, or town with a population of 50,000 or more, these municipalities are required by the statute to provide the minimum number of adequate facilities. (Section 144.796 (2)). A county with a population of less than 50,000 is also required to provide adequate facilities if they do not otherwise exist. (Section 144.796 (3)).

The minimum number of waste separation and recycling collection facilities depends on the population of the municipality, and ranges from zero, if the population is less than 10,000, to three, if the population is 100,000 or more.

In terms of adequacy of a facility, it is required "to be listed in a directory issued by the department and accessible to the public." (Section 144.796 (5)). Unless determined economically infeasible by the state, each waste separation and recycling facility is required to provide a separate bin for at least plastic, newsprint, aluminum, and glass, to be considered adequate.

This provision went into effect in July 1986, but at least as late as October 1986, the state had chosen not to enforce the plastics recycling requirement due to lack of markets. As of fall 1986 the state was trying to coordinate recycling collection in neighboring communities to collect enough plastic milk jugs in adequate amounts for Midwest plastics recycling firms to pick up.

Although mandatory plastics recycling programs are still in their infancy, it has become apparent that available markets are instrumental to the effectiveness of such programs. In the past, the plastics industry has supported the mandatory aspects of the New Jersey law.

Pennsylvania

The State of Pennsylvania has proposed legislation before the State House which would required the source separation and recycling of certain materials, which could include plastics. The legislation includes provisions for market development and waste reduction studies, both of which should impact plastic. Procurement of materials with recycled content by state agencies is considered a major feature of the bill.

The source separation and recycling legislation is known as Senate Bill 528, P.N. 1519, and is entitled "Municipal Waste Planning, Recycling and Waste Reduction Act."

General provisions of the legislation:

1. Sets a 25% recycling goal by 1997.

2. Sets goals for increasing waste reduction efforts in the state and to encourage government procurement and use of materials with recycled content.

3. Sets a goal for increasing educational and information programs in the area of recycling and waste reduction.

The legislation establishes a Recycling Fund for use as follows:

A. At least 70% for grants to municipalities for development and implementation of recycling programs, recycling coordinators, market development and waste reduction studies and implementation and research conducted by the Department of Transportation.

B. Up to 10% for grants for feasibility studies for waste processing and disposal facilities, except facilities for combustion of waste not operated for the recovery of energy.

C. Up to 30% for public information, public education and technical assistance concerning recycling and waste reduction, research and demonstration projects, planning grants and the host inspector training program.

In addition, the bill includes specific recycling and waste reduction requirements:

1. Within two years of passage of the bill, communities with a population exceeding 10,000 will be required to establish and implement source separation and collection programs for at least three materials in addition to leaf waste. The three materials shall be chosen from the following: clear glass, colored glass, aluminum, steel and bimetallic cans, high-grade office paper, newsprint, corrugated paper and plastics.

2. Within three years of passage of the bill, communities with a population between 5,000 and 10,000 and densities of more than 300 persons per square mile will also be required to set up similar separation and collection programs for the materials described in the above paragraph.

3. Within two years after the effective date of the Act, all state agencies, including state owned universities, must develop and implement source separation and collection programs for recyclable aluminum, office paper and corrugated cardboard at a minimum. (This provision could possibly be expanded to cover plastics recycling.) Also within two years, each Commonwealth agency must implement a waste reduction program for these and other materials used in agency operations.

4. The Department of General Services will be required to review and revise its existing procurement procedures and bid specifications to eliminate procedures which discriminate against materials with recycled content and to encourage the use of these materials by State government agencies.

Vermont

As previously discussed, H.196 is a bill with various and far-reaching provisions regarding the management of solid waste. Among other provisions on waste reduction, recycling, and considerations of product and packaging bans and taxes, the law requires its State Solid Waste Management Plan to include strategies on source separation. Section 6604 (a)(2)(A) states that the plan shall include:

> "methods to reduce and remove material from the waste stream, and to separate, collect and recycle, treat or dispose of specific waste materials that create environmental, health, safety, or management problems,...This portion shall include strategies to assure recycling in the state, and to prevent the incineration or other disposal of marketable recyclables."

PLASTIC CODING OF CONTAINERS

Wisconsin

The state of Wisconsin has adopted a bill regulating the coding of plastic bottles. AB 650 requires plastic containers to be labelled to show the type of resin they are comprised of.

Pennsylvania

This state's Department of Environmental Resources is a member of the Great Lakes States Recycling Officials Committee and a member of a similar committee of Northeastern States. The groups recently proposed to the Society of Plastics Industries that plastic container manufacturers label plastic products with a coding to identify the type of resin used in the product. The Society responded by adopting a policy encouraging its members to voluntarily adopt coding, and is developing a coding format.

COORDINATED MULTI-STATE EFFORT

There have been efforts to create a regional plan between at least 16 states to reduce packaging and facilitate recycling. These states believe that putting a code on every plastic container to show what it is made of and whether it can be recycled, is a step in the right direction towards successful national plastic recycling.

PROHIBITION OF MARINE POLLUTION

MARPOL ANNEX V International Treaty

This treaty embodies a multi-national effort to deal with the problem of pollution of the world's oceans. MARPOL is an international agreement that regulates pollution generated by international shipping. Annex V of the treaty governs ship-generated garbage.

Annex V prohibits ships from discharging any plastics overboard and bans disposal of any other floating garbage within 25 miles of shore. Annex V requires ports to provide garbage reception facilities for ships.

An extremely important provision of Annex V prohibits international shipping from dumping any solid waste, including plastics, into the waters off of Texas, and the other Gulf Coast states. The Gulf of Mexico would be designated a "special area"; this provision gives Gulf Coast states protection from off-shore garbage dumping.

Regulation 5 of Annex V covers the disposal of garbage with special areas. This regulation prohibits the disposal into the sea of "all plastics, including but not limited to synthetic ropes, synthetic fishing nets and plastic garbage bags..."

As noted in the "Adopt-A-Beach" program of Texas discussed below, this treaty promises a long-term solution to the problem of garbage, much of it plastics, washing up on the beaches of Gulf Coast states. The Gulf of Mexico joins the Mediterranean Sea, the Baltic Sea, the Red Sea and the Persian/Oman Gulf as waters granted the status of a "special area."

On October 13, 1987, the U.S. House of Representatives passed H.R. 940. This bill implements MARPOL, Annex V in the United States. Annex V was then unanimously ratified by the U.S. Senate on November 5, 1987.

H.R. 940 places enforcement authority in the U.S. Coast Guard, which will adopt regulations requiring a solid waste management plan for all ships and a daily log entry by each ship's captain certifying that their ship's garbage has been disposed of in accordance with Annex V and U.S. law. Violators will be subject to fines of up to $25,000 per incident.

U.S. ratification of Annex V pushed the percentage of world shipping tonnage over the required 50% mark and would allow the treaty to come into force one year from that date. At least 29 countries have now ratified Annex V, including the Soviet Union.

The ratification of this treaty will have a direct impact on the kind and amount of solid waste which is dumped at sea. Estimates from the National Academy of Sciences show that the world's merchant shipping fleet discards 450,000 plastic containers, along with 4,800,000 metal and 300,000 glass containers at sea <u>every day</u>.

Much of this would-be refuse will now be prevented from reaching ocean waters with the enforcement of Annex V of MARPOL. This also means that more plastic, metal and glass containers will be disposed of in a responsible way, allowing increased opportunity for recycling of our natural resources.

<u>California</u>

SB 896--

This bill created legislation prohibiting the dumping of plastic material into the waters or on the land of the state of California.

Senator Marks of the California Legislature introduced a bill prohibiting the dumping of plastics in the environment. This bill became law in March 1987. This bill prohibits any person from discarding or dumping plastic material on or in the land or into the waters of the state, notwithstanding any other provision of law. The bill imposes a state-mandated local program since violation of the prohibition would be a misdemeanor.

Existing law prohibits any person from depositing or dumping garbage in specified public places, unless the property is designated for that use or the property is owned by that person, as specified. Existing law also prohibits the depositing of garbage in the navigable waters of the state.

This statute adds to Section 4478 of the Health and Safety Code the following:

(a) "Notwithstanding any other provision of law, no person shall discard or dump plastic material including raw plastic pellets or finished plastic products, on or in the land or into the waters of the state."

(b) "For purposes of this section "finished plastic products" includes, but is not limited to, plastic holders of multipackage beverage, plastic packing bands, and plastic coated or lined boxes."

Bill Endorsing a Study of Marine Pollution--
In September 1987, AB 780 was introduced, which would have required the California Waste Management Board, in consultation with affected public agencies, representatives of the plastics industry, affected user groups, and affected environmental groups to conduct a review, as specified, resulting from accumulations of nonbiodegradable debris and to submit a report of the review to the Legislature. The bill was vetoed by the Governor. The statute, if enacted, would have read as follows:

Section 1. (a) "The California Waste Management Board, in consultation with other affected local, state, and federal agencies and departments, representatives of the plastics industry, affected user groups, and affected environmental groups, shall conduct a review of existing studies, literature, and data regarding pollution of the marine and land environment resulting from accumulation of nonbiodegradable debris, with an emphasis on plastics and styrofoan.

(b) The review shall include, but not be limited to, all of the following:

(1) Major sources of this pollution.

(2) The impact of this pollution, particularly as it affects marine mammals and birds.

(3) Voluntary actions to reduce this pollution which could be taken by plastic product manufacturers or by companies which use plastics to package their products.

(4) Regulatory actions which could be taken by the state to abate this pollution."

The potential of this law is unclear, but it could have yielded a great deal of information useful to the recycling effort. Without this law, and the information it would have generated, the Legislature is much less well-equipped to deal with the problem of marine pollution.

<u>Texas</u>

The Texas Adopt-A-Beach Program--
In recent years, Texas has received tons of garbage on its beaches, perhaps 75 to 90 percent of which is the result of offshore dumping in the Gulf of Mexico. The Adopt-A-Beach program was created by Texas Land Commissioner Garry Mauro.

The purpose of the program is to draw public attention to the beach garbage problem and promote a comprehensive approach to its solution. Through the program, private businesses, environmental and civic organizations, and other groups agree to maintain a designated segment of a public beach for one year, conducting three cleanups for that period. The sponsoring groups receive adoption certificates, and a certificate of appreciation is issued to each volunteer who participates in a cleanup.

Since the program's first coastwide cleanup in 1986, over 10,000 Adopt-A-Beach volunteers have picked up more than 445 tons of garbage along the Texas Coast. At least 140 groups have adopted the entire 172 miles of accessible Texas beach. With adoption completed the program will concentrate on an educational program to be used in schools and communities to create more public awareness of the beach garbage problem.

LITTER CONTROL PROGRAMS AND ANTI-LITTER LAWS

<u>California</u>

California Anti-Litter Act of 1987--
A bill recently passed by the California legislature known as AB 544, created a coordinated statewide anti-litter education program for the state. The California Waste Management Board (CWMB) is required to establish a Litter Task Force by July 7, 1988, which will be comprised of eleven state agencies. The CWMB will then consult with the Litter Task Force and submit a proposal to the legislature on the development and implementation of the education program.

The legislature declared that the litter problem in California is "worsening at an alarming rate," and that "a concerted effort is required to provide an effective litter control program."

The effect on plastics as a waste material by this bill is potentially substantial. Such a litter program could certainly include educational efforts on the use of plastics in the packaging industry. The use of plastics by fast-food restaurants and mini-markets is likely to be addressed.

AB 898 Enforcement of litter laws--
Under existing law, it is a violation for any person to throw, deposit, place or dump any bottle, can, or other specified object onto the highway. This bill declared that the enforcement of the state's litter laws is an essential component of effective litter control.

The bill would, when material is thrown or deposited from a vehicle, create a presumption that the driver of a vehicle has caused the act. The bill transferred $1,000,000 from the General Fund to the California Litter Enforcement Fund, which the bill created, for allocation by the Controller to local governments, for the costs of issuing notices to appear for violations.

As this act establishes stricter interpretations of litter violation and provides fiscal incentives for local governments to enforce California's litter laws, it could result in more recycling efforts undertaken by private individuals and companies.

Virginia

The state of Virginia conducts one of the most comprehensive litter control programs in the U.S. In 1976, the Virginia General Assembly passed the Litter Control Act, creating the Virginia Division of Litter Control and the funding to begin programs to educate society.

The Division is funded solely by special taxes levied on businesses and industries. The Litter Control Act mandates that a minimum of 50% of these monies be channeled as yearly litter control grants to Virginia communities.

Every city, county and incorporated town in Virginia is eligible to receive litter control grants. Participation in this funding program has risen close to 100% of Virginia communities.

The Division of Litter Control works to support and enhance the network of local programs through grants and program development, education and communication. Grants provide "seed money" and incentive for the community-based committees to begin specific programs. The Division also provides a step-by-step manual for developing and operating a community litter control program. Another major effort by the Division is to educate children in anti-littering ethic.

Washington

The state of Washington has implemented the Litter Control Act of 1971 as an alternative to a bottle bill. The Act authorizes the State Department of Ecology to carry out a program for the reduction of litter.

The Department's activities are funded by two sources:

- small fines upon individuals who break the law, and

- a fixed tax per million dollars of sales on all forms of packaging at each stage of the sale.

This includes packaging during manufacturing, wholesaling, distribution and retailing.

Products which are subject to taxation are glass containers, metal containers, and plastic materials, as well as food, groceries, carbonated beverages, beer, newspapers and magazines, among others.

RECYCLING SUPPLY STRATEGIES

Container Deposit Laws/Bottle Bills

A number of states have passed bottle bills, which generally require the consumer to pay a deposit when he purchases beer or soft drinks. When the consumer returns the container to the grocery store or other retailer, his deposit is given back to him.

This analysis does not include every state with a bottle bill. Instead, it gives examples of different approaches that have been tried.

Oregon

The state of Oregon was the first to implement a bottle bill. The bill grew out of a desire to solve the increasingly voluminous litter problem on the state's public roads and beaches.

The provisions of Oregon's Bottle Bill are as follows:

1. "Beverage" is defined as beer, malt beverage, mineral water, soda water, and carbonated soft drinks.

2. All beverage containers must have a minimum refund value clearly marked, paid by distributor to dealer, and by dealer to customer.

3. Dealers and distributors may not refuse to accept and refund the deposit on empty beverage containers of the kind, size, and brand which they sell. However, as provided in the 1981 Amendment, a dealer may refuse to accept more than 96 empty containers a day from any one person if a notice is posted stating acceptance times for larger quantities. The dealer may refuse to accept excessively dirty containers.

4. A "certified" beverage container is defined as a container reusable by more than one manufacturer; capacity and shape may be set by the Oregon Liquor Control Commission.

5. Minimum refund value of each container is five cents, except for certified containers, for which the minimum refund is two cents (Actual refund values go as high as twenty cents for refillable containers.)

6. Redemption centers may be established by any person in order to accept returned containers.

7. As of March 1, 1979, no beverage may be sold in any container that has a detachable metal part opening the container through the use of a metal ring or tab without the aid of a can opener.

8. Metal beverage containers connected by a separate holding device constructed of plastic rings or other material which will not decompose within 120 days of disposal may not be sold or offered for sale (1977 Amendment).

The Deposit System of Oregon--

The Bottle Bill called for a mandatory refund value on all beer and soda containers sold in Oregon after September 30, 1972. The bottlers and businesses affected by the refund legislation have initiated deposits to be in compliance with the law.

The handling system for refillable bottles was already in place when the law went into effect. That system was expanded to include single-use bottles and cans.

Deposits on refillable containers originate with the brewer or bottler who wants the container returned. The deposit, ranging from two to twenty cents per bottle, is added to the wholesale price charged the distributor.

The distributor initiates the deposit, the minimum of five cents, on single use bottles and cans. The deposit charge is passed on to the retailer and the consumer.

The deposit is refunded when the empty container is returned. After the consumer returns the empties to the store, the distributor picks them up from retailers during business hours. The refillable bottles are shipped back to the brewery or bottling plant. Recycling firms buy up the aluminum, plastic, and glass single-use containers returned to the distributor's warehouse. In a recent survey, only five to seven percent of the containers were not being returned.

The brewery or bottling plant keeps the unredeemed deposits on refillable bottles, reducing the cost of replacing the bottle. Distributors offset their handling and transortation costs with the unredeemed deposits on single-use containers as well as through the sale of returned containers for recycling. Oregon's Bottle Bill has no provision for a handling fee to compensate the retailer for any handling expenses incurred, which have been estimated to be as high as two to two-and-one-half cents per container.

The deposit system operates smoothly with practically no state or local government involvement.

The Law's Effects--

The Bottle Bill has reportedly had several positive impacts on Oregon's solid waste problem.

1. Roadside litter: Beverage container litter was nearly eliminated. The total litter rate was reduced substantially.

2. Solid waste disposal: Very large reduction in the beverage container proportion of the solid waste stream. Substantial savings in trash pickup, hauling, and landfilling.

3. Recycling: Development of national recycling markets for plastic from PET containers. Positive effect on the recycling of other non-beverage container items including soft plastic.

California

AB 2020: Recycling Legislation--

The California Legislature has recently passed a bottle bill, which took effect October 1, 1987. This bill is known as AB 2020, and is entitled "the California Beverage Container Recycling and Litter Reduction Act." The bill was a compromise between bottle bill proponents and opponents, who were tired of nearly twenty years of annual battles in front of California's legislature and voters.

The stated purpose for enacting the bill was to increase the level of recycling of beverage containers. Like all bottle bills, AB 2020 sets up a procedure by which a deposit (1 cent) on containers is initiated and later refunded.

Unlike other bottle bill states, the California law requires massive state government involvement in regulating the operation of the deposit system. For example, there is no direct responsibility for a grocer to take back the container.

Beginning October 1, 1987, consumers were able to redeem aluminum cans, plastic bottles, and glass bottles, except for refillables, for a minimum of a one-cent refund. In general, if the rate of return of containers is low, the consumer will get more money. If the rate of return is high, the amount the consumer receives declines.

Here is how the system works:

1. The container is returned by the consumer, and then a recycling center/grocer pays the consumer the deposit value in exchange for the empty container.

2. Soft drink and beer distributors pay the state Department of Conservation one cent for every container they sell. The distributors are permitted to retain a percentage of the redemption value in order to recover their own administrative costs.

3. The state administrative agency, the Department of Conservation, has a fund for container deposits, called the California Beverage Container Recycling Fund.

4. Because not all containers will be returned, an intricate allocation formula is used to determine what happens to the unreturned deposit money.

Unreturned deposit money is used as follows:

- Ten percent is spent on litter abatement and recycling activities.

- Another ten percent is spent on recycling information, education and promotion.

- Twenty percent is allocated for convenience incentive payments. These are bonuses to encourage recycling centers in remote areas.

- The balance is reserved for redemption bonuses, so that consumers receive more than one cent.

  Bonuses are determined by container type. For example, if only 1 out of 10 plastic soda containers is being returned, then 9 of 10 cents for deposits goes to the unreturned deposit fund. Sixty per cent (5.4 cents per container) would be given to the consumer on top of his original 1 cent, for a total of 6.4 cents.

5. In addition, beverage manufacturers pay a processing fee to the Department of Conservation (DOC) for each container they sell to grocers/retailers or distributors (wholesalers).

6. The recycling center/grocer/retailer will sell empty containers to processors in exchange for:

   a. the redemption value (1 cent) of all containers, plus a one percent handling fee;

   b. any applicable redemption bonus the recycler is entitled to, and;

   c. a processing fee equal to the recycling center's actual, unrecovered costs plus a reasonable rate of return.

7. Processors, in turn, are paid by the DOC:

   a. the redemption value of all the containers they recovered from the recyclers, plus two percent to cover the processor's administrative costs;

   b. any applicable redemption bonus and a processing fee.

Under reporting requirements, every processor submits a monthly report to the DOC stating the number of empty containers it received from recycling centers. Every distributor submits a monthly report to the state on the number of beverages it sold and the number of empty containers it received to be refilled.

The DOC has implemented an auditing system to ensure that the information collected, and redemption values and bonuses paid, comply with the purposes of the Act.

Not surprisingly, all of this requires a great deal of oversight. The State Department of Conservation (DOC) is responsible for certifying recycling center operators, processors and non-profit dropoff programs. In addition, the DOC is responsible for ensuring there is at least one recycling center in each convenience zone (i.e., within one-half mile radius of every grocery store that has gross annual sales of more than two (2) million dollars).

It is anticipated that there will be 2,743 zones established in California. With the establishment of a convenient and profitable means of recycling materials, the general public should be much more willing to recycle.

If no recycling center is in an area, the DOC will offer economic incentives (Redemption Bonuses and Convenience Incentive Payments) to encourage recyclers to begin new operations in that area.

Until such a center is established, the dealers and retailers will be required to take back the containers. If, after a fixed period of time, no recycling center has been established, the DOC will require retailers to redeem all types of containers or pay a fine of $100 per day until a recycling location is established.

The DOC may also examine the accounts and records of beverage distributors, manufacturers and beverage container manufacturers. If any of the above fail to make sufficient payments to the California Beverage Container Recycling Fund, a fine (plus interest) may be levied on them.

Future Increases in Consumer Deposits

If, by 1989, the number of containers redeemed is less than 65% of all those purchased, then the deposit will be increased to 2 cents. If the redemption rate remains less than 65% by 1992, the deposit will increase to three cents.

Effect of the Bottle Bill on Plastics

The Act should significantly impact the recovery of PET plastic containers in California. To increase the recyclability of PET containers in California, the DOC reports that the Plastics Recycling Corporation of California (PRCC) (a nonprofit organization composed of plastics industry members) has strategically placed processing centers throughout the State.

This action is intended to support recycling centers in the selling of materials for a reasonable profit and provide stability for recycling centers that collect PET containers. This is due to substantially higher current prices being paid to recyclers for materials and shorter shipping distances which defray cost.

Furthermore, the DOC also reports that in addition to promoting the collection of plastic containers, the Department will be attempting to increase the demand for plastic beverage containers that can be remanufactured into new products. This effort will consist of programs which will promote the purchase of products made from recycled plastic.

While the Act mainly focuses on recycling activities, AB 2020 also provides funds for litter cleanup and abatement. These funds will be expended in the form of grants to certified community conservation corps, either existing or those established in the future, which are designated by a city or a city and county to perform litter abatement and related activities. The remaining funds shall be expended by contract with local conservation organizations.

Vermont

The State of Vermont also has a beverage container law. It is found in Title 10, Vermont Statutes Annotated, Chapter 53, Section 1521-1527. The law applies to plastic PET bottles, cans, and glass for beer, malt beverages, mineral water, soda water and carbonated soft drinks. This law was implemented in September 1973.

The Deposit - Redemption Cycle--
A five cent minimum deposit must be charged on containers sold at retail. It can be initiated at three different stages: the manufacturer or bottler, the distributor or wholesaler, or the retailer or dealer. Glass containers destined for refilling usually have the deposit initiated by the manufacturer or bottler. Most other deposits, including those on plastic bottles are initiated by the distributor or wholesaler.

Containers are redeemed for the refund value at any store or redemption center which sells the kind, size and brand. Retailers and redemption centers are reimbursed the refund value by the distributor, and are paid a handling fee (20% of the refund value or a minimum of 2 cents).

Distributors normally pick up containers from retailers and redemption centers on regular schedules or upon request. While glass containers are typically returned for refilling, PET bottles and cans are sold for recycling.

New Jersey

Two bills requiring deposits on beverage containers have been introduced into the New Jersey Legislature. S-3535 would place a 10-cent deposit on all 100% recyclable containers such as glass and aluminum. All other containers would have a refund value of 25 cents.

The second bill, A-4261, would put a 10-cent deposit on refillable containers, a 15-cent bounty on one-way glass and bimetallic containers, and 25 cents on every other type of beverage container.

District of Columbia

Voters in the District of Columbia had the opportunity to approve or reject a beverage container deposit law on November 3, 1987. Proponents were able to place the measure on the ballot by obtaining some 22,000 signatures on initiative petitions.

The measure is unique in that proposed deposits will vary by container size, going from five cents for each container that holds less than one liter, up to twenty cents for containers with a capacity of two liters or more.

Wisconsin

The Wisconsin legislature is considering a bill that will require a deposit of at least three cents on each beverage container sold in the state.

GOVERNMENT GRANTS AND LOANS TO INCREASE RECYCLING SUPPLY

At least nine states have adopted funding programs to encourage increased recycling. Typically, these programs offer grants or loans to foster development of dropoff, buyback, and curbside recycling programs. Often, the program startup costs are paid by the state, while the ongoing operational costs are paid by the recipient. Some grants have also been given to aid the development of intermediate and final processing of waste plastics.

California's SB 650 program was typical of these recycling grant and loan programs. The California Litter Control, Recycling, and Resource Recovery Act of 1977 was administered by the California State Waste Management Board, which gave out or loaned more than $30 million. Recipients included local government, non-profit, and private sector recyclers.

RECYCLING DEMAND TECHNIQUES

Recycling Procurement Standards

1. 1976 Resource Conservation and Recovery Act (RCRA)

RCRA is a statute which, among other things, requires the purchase of products containing recycled materials by the federal government.

It is a widely-held belief that the largest barrier to large-scale recycling is the absence of markets for materials recovered from the waste stream.

An official federal preference for the purchase of recycled products would provide a powerful stimulus for the development of markets for recycled materials since the federal government has such tremendous spending power. By its procurement of recycled materials these federal agencies might also serve as a role model for other government agencies to emulate.

Congress was aware of this influential buying power and stated in RCRA that all federal agencies were required to purchase products with "the highest percentage of recovered materials practicable," under guidance to be provided by the Environmental Protection Agency. The preferential procurement plan was slated to begin in 1978.

The EPA took no action between 1976 and 1984, at which time Congress again ordered the EPA to issue final guidelines for the program by its amendment to RCRA in 1984. Although the Congressional amendment mandated that guidelines on the procurement of recycled materials be issued, the EPA has only issued guidelines for two materials to date: paper and ash.

The Environmental Defense Fund, which seeks to stimulate growth of markets for recycled materials such as plastic, has recently filed a lawsuit to force the EPA to comply with RCRA. The adjudication of this lawsuit could have a huge impact on the market for items such as recycled plastic.

State Procurement Requirements

In most states, the demand for many products which could be made with recycled materials is dominated by large government purchasers. For example, the largest demand for paper products in California is from state government, the University of California system, the California State University System, and the State's community college system.

Unfortunately, most states have not reviewed their procurement specifications for prejudice against use of recycled materials. In the early 1980s, the state of California sought to revise its oil purchase specifications, which mandated use of virgin lubricating oil even though there was no difference between recycled and virgin oil products.

Appendix B

RECYCLING ACT OF 1988

I

100TH CONGRESS
2D SESSION

H. R. 4454

To establish programs to promote recycling, and for other purposes.

IN THE HOUSE OF REPRESENTATIVES

APRIL 26, 1988

Mr. COURTER (for himself, Mr. SMITH of New Jersey, Mr. GALLO, and Mr. SAXTON) introduced the following bill; which was referred jointly to the Committees on Science, Space, and Technology, Education and Labor, Energy and Commerce, and Merchant Marine and Fisheries

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A BILL

To establish programs to promote recycling, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SECTION 1. SHORT TITLE.

This Act may be cited as the "Recycling Act of 1988".

SEC. 2. DEFINITIONS.

For purposes of this Act, the following definitions shall apply:

(1) The term "Administrator" means the Administrator of the Environmental Protection Administration.

(2) The term "Center" means the national center for plastics recycling established under section 3(a).

(3) The term "recycling" means the beneficial reuse or remanufacture of, or the recovery of energy value from, commercial and non-commercial products and materials.

SEC. 3. NATIONAL CENTER FOR PLASTICS RECYCLING.

(a) ESTABLISHMENT.—(1) The Center for Plastics Recycling Research of Rutgers-The State University of New Jersey, in Piscataway, New Jersey, is hereby established as the national center for plastics recycling.

(2) The Center shall not be considered an agency of the Federal Government or an instrumentality of the United States for purposes of the laws United States.

(b) CONTRACT WITH ADMINISTRATOR; FUNCTIONS.—(1) The Administrator shall contract with the Center to carry out the functions described in paragraph (2).

(2) Under the contract entered into with the Administrator under paragraph (1), the Center shall—

(A) establish and operate a clearinghouse of information relating to plastics and disseminate such information through newsletters, journals, and other appropriate communications;

(B) conduct the research activities described in subsection (c); and

(C) select 4 other colleges and universities, in such manner as it considers appropriate, to assist it in conducting the research activities described in subsection (c), and shall make a grant to each such college or university in the amount of 50 percent of the funds required by such college or university to conduct its assigned activities, with the remaining funds being provided by the State in which such college or university involved is located.

(c) TOPICS OF RESEARCH.—The research activities conducted by the Center and by the colleges or universities described in subsection (b)(2)(C) shall include, but shall not be limited to—

(1) a study to determine the plastic products and materials not currently recycled in significant amounts which are found in the largest amounts by volume and by weight in municipal solid waste streams;

(2) a study of which post-consumer plastic products and materials are best suited for recycling, and of ways to encourage the plastics industry to include recyclability as a basic design goal for the long-term resolution of the issue of plastic recycling;

(3) research into the development of plastics recycling methods and systems, including collection, sorting, reclamation, and end-use manufacturing, which

will improve energy conservation through the preservation of the chemical energy content of recycled plastic waste products and materials; and

(4) an analysis of which plastic waste products and materials present potential environmental risks through current disposal pathways and of the role of plastics recycling in reducing such risks, including an analysis of issues relating to biodegradable materials and the impact of plastics on marine life.

(d) AUTHORIZATION OF APPROPRIATIONS.—There is authorized to be appropriated to carry out the purposes of this section for each of the first 3 fiscal years beginning after the date of the enactment of this Act the sum of $5,000,000, of which not more than 10 percent may be used by the Center and the colleges or universities described in subsection (b)(2)(C) for administrative purposes.

SEC. 4. PUBLIC EDUCATION PROGRAM ON RECYCLING.

(a) OUTREACH PROGRAM.—The Secretary of Education, in consultation with the Administrator and the Secretary of Commerce, shall conduct a 3-year public outreach program to provide information to secondary school students, State and local governments, and the general public regarding—

(1) the harmful effects on the environment of the improper disposal of plastic and non-plastic wastes;

(2) the importance of the proper disposal of municipal wastes;

(3) the benefits of recycling; and

(4) methods to encourage voluntary recycling activities.

(b) FORMAT.—In conducting the outreach program described in subsection (a), the Secretary of Education may—

(1) organize and conduct workshops with interested groups;

(2) develop educational materials and provide them to secondary school students;

(3) record public service announcements for radio and television broadcast and develop print advertisements for newspapers, magazines, and other publications;

(4) distribute leaflets, posters, and other materials;

(5) encourage employers and labor organizations to include appropriate educational materials in their in-house publications; and

(6) provide technical assistance and other information to schools, governments, and community groups wishing to conduct educational programs on waste disposal and recycling.

SEC. 5. NATIONAL CLEARINGHOUSE ON RECYCLING.

(a) ESTABLISHMENT.—The Secretary of Commerce, acting through the Director of the National Bureau of Standards and in consultation with the Administrator, shall establish and operate the National Clearinghouse on Recycling.

(b) FUNCTION.—The National Clearinghouse on Recycling shall gather, catalog, and disseminate information on recycling-related issues and activities, including information on—

(1) current and prospective recycling technologies;

(2) the development and marketing of products made from recycled wastes; and

(3) intergovernmental arrangements for the public and private management of recycling activities.

SEC. 6. ENVIRONMENTAL PROTECTION ADMINISTRATION STUDY.

(a) IN GENERAL.—The Administrator, in consultation with the Secretary of Commerce, shall conduct a study of the adverse effects of the improper disposal of paper, glass, aluminum, and other non-plastic articles on the environment and on waste disposal, and the various methods to reduce or eliminate such adverse effects.

(b) SCOPE OF STUDY.—The study conducted under this section shall include the following:

(1) A list of improper disposal practices and associated specific non-plastic articles that occur in the en-

vironment with sufficient frequency to endanger human health or safety or to cause other significant adverse environmental impacts.

(2) A description of specific statutory and regulatory authority available to the Administrator, and of the steps being taken by the Administrator, to reduce the amount of non-plastic waste needing disposal.

(3) An evaluation of the feasibility and desirability of substitutes for those articles identified under paragraph (1), comparing the environmental and health risks, costs, disposability, durability, and availability of such substitutes.

(4) An evaluation of the impact of non-plastic materials on the solid waste stream relative to other solid wastes, and of methods to reduce those impacts, including—

(A) the status of a need for new research to develop and market recycled non-plastic articles;

(B) methods to facilitate the recycling of non-plastic materials to recover their full energy value by identifying types of non-plastic articles to aid in their sorting, and by standardizing types of non-plastic materials, taking into account trade secrets and protection of public health;

(C) the effect of existing tax laws on the manufacture and distribution of virgin non-plastic materials as compared with recycled non-plastic materials; and

(D) recommendations on incentives and other measures to promote new uses for recycled non-plastic articles and to encourage or require manufacturers of non-plastic articles to consider reuse and recycling in product design.

(6) An evaluation of the feasibility of making the articles identified under paragraph (1) from degradable non-plastic materials, taking into account—

(A) the risk to human health and the environment that may be presented by fragments of degradable non-plastic articles and the properties of the end-products of the degradation, including biotoxicity, bioaccumulation, persistence, and environmental fate;

(B) the efficiency and variability of degradation due to differing environmental and biological conditions; and

(C) the cost and benefits of using degradable articles, including the duration for which such articles were designed to remain intact.

(c) CONSULTATION.—In carrying out the study required by this section, the Administrator shall consult with the heads of other appropriate Federal agencies, representatives of affected industries, consumer and environmental interest groups, and the public.

(d) REPORT; COORDINATION WITH OTHER STUDY.—(1) Not later than 1 year after the date of the enactment of this Act, the Administrator of the Environmental Protection agency shall submit a report to Congress containing the results of the study required by this section and recommendations in connection therewith.

(2) The Administrator shall coordinate the study required by this section with the study of methods to reduce plastic, plastic pollution required under section 2202 of the Marine Plastic Pollution Research and Control Act of 1987 (Public Law 100–220; 42 U.S.C. 6981 note), and shall integrate the results of such study and of the study required under this section into a single comprehensive study on methods to reduce waste pollution and encourage recycling.

SEC. 7. GRANTS FOR DEMONSTRATION PROGRAMS.

(a) IN GENERAL.—The Administrator shall make grants to eligible State and local governments to cover the Federal share of the costs of conducting demonstration programs related to recycling.

(b) CRITERIA FOR ELIGIBILITY.—The Administrator shall develop and publish such application requirements and other criteria for determining the eligibility of a State or local government to receive a grant under this section as he considers appropriate, except that he shall award not less than 1 grant each year to a State whose laws mandate the collection, for purposes of recycling, of 2 or more types of household or commercial wastes.

(c) PROGRAMS INVOLVED.—The demonstration programs referred to in subsection (a) may include, but need not be limited to, programs which—

(1) promote the collection and separation of recyclable wastes at the local level;

(2) identify potential buyers of recyclable materials and recycled products;

(3) promote the use of recyclable materials in the manufacture and distribution of products in an environmentally sound manner; and

(4) develop facilities to recover the energy value of waste products.

(d) FEDERAL SHARE.—The Federal share of the costs of conducting demonstration programs related to recycling is 50 percent, and the non-Federal share of such costs may be provided in cash or in kind by State or local governments or private sources.

(e) Authorization of Appropriations.—There is authorized to be appropriated to carry out the purposes of this section the sum of $15,000,000 for each of the first 3 fiscal years beginning after the date of the enactment of this Act.

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