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# PLASTICS RECYCLING ACTION PLAN FOR MASSACHUSETTS– PART I

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## ABSTRACT

This study assesses the feasibility of, and designs a plan for, including recovery of household plastic discards in the statewide multi-material recycling program of the Commonwealth of Massachusetts. Part I of the study, presented in this issue, discusses the types and amounts of plastic materials found in the waste stream, methods for collecting them, technologies for recycling them, and markets for the recycled products. Part II, appearing in the following issue, concludes that plastics recycling should be pursued and describes an action plan for integrating the plastics component into the Commonwealth's recycling program. Part II also contains technical appendices.

## INTRODUCTION

This report assesses the feasibility of including plastic discards in the statewide recycling program. Part I examines the types and quantities of plastics in the waste stream, the methods best suited for plastic collections, the technologies available for processing and remanufacturing the plastic, and the long-term outlook for material markets. Part II concludes that plastic recycling should be pursued and presents an action plan with specific mechanisms for implementing large-scale plastic recycling. It cites key areas where further research and development are needed, and suggests governmental initiatives that will speed recycling growth.

*This reasearch was conducted in cooperation with the state of Rhode Island. The background data in this document are for Massachusetts only; the action plans were developed to match each state's needs. Readers interested in plastics recycling programs in Rhode Island should contact the Rhode Island Department of Environmental Management, 9 Hayes Street, Providence, Rhode Island 02908, (401) 277-3434.

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The plastics action plan is one component of a comprehensive recycling and composting program designed to divert at least 25 percent of the solid waste going into Massachusetts' overburdened landfills, three-fourths of which are expected to close by 1990. This report lays out a framework for integrating plastics into the statewide recycling program, which calls for the phase-in of twelve multi-material curbside collection programs across the Commonwealth by the year 2000.

Each regional program will serve a cluster of towns and cities (average population 500,000) with weekly curbside pick-up of household recyclables (glass containers, cans, newspapers, plastics, etc.). Collected materials will be delivered to a central material recovery facility (MRF) to be sorted, upgraded and marketed for use as industrial raw materials.

To optimize citizen participation and recovery rates, the "user-friendly" program provides each participating household with a handy storage container as a constant reminder to recycle. It requires only a simple sorting of non-recyclables from recyclables. On trash pick-up day, the resident simply puts the recycling container at the curb for pick-up by a recycling truck.

State financing will be used to provide participating communities with specialized collection vehicles, household set-out containers, and public education, and to assist in MRF construction. In return, communities may join a region by passing local mandatory recycling ordinances and agreeing to allocate part of their disposal-cost savings to operate the collection service. Every ton of recyclables accepted by the MRF at little or no charge saves the average Massachusetts community a dump fee of $50.

The Massachusetts Solid Waste Act of 1987 allocated $10 million to municipal and agricultural composting programs and $35 million for regional and community recycling programs. This is an unprecedented commitment by the Commonwealth to mobilize sound waste management alternatives.

## 1. WHY PLASTICS?

### First Growth, Then Problems

Plastics are everywhere, a miracle of modern life. They are an incredibly versatile tool of society, and much more than a new way to package milk or fabric softener. Plastic means contact lenses, artificial hearts, more fuel-efficient automobiles, dentures, microwave ovens, portable computers.

This man-made family of materials exploded onto the American scene during the years of rapid economic growth after the Second World War. Since the 1970s, the U.S. plastics industry has continued to grow at a breathtaking rate, with production jumping from nineteen billion pounds in 1972 [1], to an estimated fifty-three to fifty-five billion pounds in 1987 [2, 3]. Gross sales, at $138 billion in 1985, are predicted to hit $345 billion in the year 2000, with production pushing towards 76 billion pounds per year [1].

Yet this economic bonanza has spawned huge and complex problems with disposal, pollution and long-term resource use. In its present, throw-away form, plastic production and use are fast becoming a liability for society. Plastic is clogging the world's oceans, overflowing from its landfills, producing pollution during production and again wnen burned in incinerators, and consuming large quantities of non-renewable oil and natural gas to make not just artificial hearts but throw-away products by the billions. As the problems mount up, the old misconception that plastic can't be recycled is being turned on its head: not only *can* it be recycled, *it must be recycled.*

## Plastic Is a Pollutant of Land and Oceans

Improper disposal of plastic products, either as litter or as waterborne trash, has caused worldwide problems ranging from damaged tourist trade at beaches and scenic areas to massive kill-offs of marine wildlife. Annual Coast Week clean-ups on Cape Cod net hundreds of pounds per square mile of plastic utensils, fishing gear and other debris left behind by picnickers or dumped overboard by boaters. Plastic tampon applicators escape the Boston sewage treatment plant and wash up on Massachusetts beaches by the thousands [4].

Plastic ocean pollution in U.S. waters—ranging from discarded six-pack yokes to lost fishing nets to plastic bags—is blamed for the death by entanglement or ingestion of about 100,000 marine mammals annually, including endangered whales and turtles. The National Academy of Sciences estimates that commercial fishing fleets yearly dump fifty-two million pounds of packaging material into the sea and lose about 300 million pounds of indestructible plastic fishing lines and nets [5]. Two to four times more plastic debris is washing up on North Atlantic beaches and shorelines than fifteen years ago [6], and the Worldwatch Institute warns that large quantities of floating plastic particles have been found in the most remote areas of the world's oceans [7].

Plastics do not rot, rust, dissolve, biodegrade, or evaporate when exposed to the elements. Discarded polystyrene cups, plastic utensils and straws, used once, will remain a problem for centuries.

## Plastics Bloat the Waste Stream

In the Commonwealth's shrinking landfills, plastics represent an estimated 8 percent by weight of solid wastes [8], yet take up two to three times that level in volume [9]. Given $50/ton tip fees and total disposal costs including collection approaching $100 per ton in many areas, the cost to Massachusetts' citizens for plastic disposal is estimated at $24 to $48 million per year.[1]

The plastic industry recommends incineration of plastics for energy recovery as a promising alternative to landfilling, since plastics, with their high content of oil and natural gas, can boost the energy value of trash. But waste-to-energy

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[1] Calculation of the Massachusetts Division of Solid Waste Management.

facilities have become increasingly difficult to site because of high costs and citizen concerns over air emissions and disposal of ash residue.

## Plastic Is a Non-Renewable Resource

The waste-to-energy approach also places at risk the future of the plastics industry, whose existence is tied to plentiful supplies of oil and natural gas. Full development of recycling systems offers a win-win scenario that makes plastic a sustainable resource for industry and helps government safeguard public health and relieve pressure on waste-disposal capacity.

Petroleum and natural gas are both the raw materials of and the energy source for plastics production. Continued availability of these scarce, non-renewable resources is a critical issue underlying use and disposal of plastics. According to several sources, known world-wide reserves of economically accessible petroleum and natural gas have remained level, despite huge exploration expenditures since 1970, and can be expected to last only thirty-two to sixty years at present consumption rates [10, 12].

The national dependence on petroleum and natural gas for plastics and other uses carries larger threats, including the volatile military and political situation in the Middle East, where one-half of world reserves are located. Now at 38 percent of U.S. consumption, petroleum imports are expected to rise dramatically in the next decade as domestic reserves are depleted [12]. This will coincide with the end of the so-called glut of cheap oil, widely expected to revert in the mid-nineties to shortages and price shocks like those of 1973 and 1979 [13]. Thus, our use of plastics and other petroleum and natural gas products plays a key role in future resource and economic security.

This scenario promises inevitable, difficult choices for American consumers and leaders. Should scarce resources be used for throwaway plastics and fuel to haul more garbage greater distances, or for home heating, agricultural production and industrial growth? Recycling strategies adopted now could not only prevent abrupt economic and lifestyle changes, but bring significant economic opportunities as well. Raw material routed back into the economy will build a more self-reliant nation better positioned for long-term industrial stability.

## Plastics Recycling: Far Behind the Pace

Plastics recycling is neither impractical nor impossible. It is the optimal solution. Yet with a few exceptions, the plastics industry has lagged far behind other industries in developing capacity to recover and reuse discarded, or *post-consumer* plastics. Its one major effort, plastic soft drink bottle recycling, recovered only three-tenths of 1 percent of total plastic production in 1987. (See Table 1.)

Yet plastic recycling is nothing new. Reuse of inhouse plastic scrap has been widely practiced for decades by plastic molders and reprocessors. The challenge is to adapt existing plastic manufacturing technologies to accommodate

Table 1. Recycling Tonnage by Industry

| *Year* | *Material* | *Tons Recovered* |
|---|---|---|
| 1986 | Aluminum Cans | 616,000 |
| 1987 | Glass | 1,500,000 |
| 1987 | Paper, All Grades | 23,500,000 |
| 1987 | Plastic Soda Bottles | 75,000 |

post-consumer plastic discards. This transition is definitely underway; post-consumer plastic recycling is nearing readiness as both a waste management option and a business opportunity. Recent fast-paced developments show a number of emerging collection, processing and reuse technologies, along with strengthening markets for reclaimed post-consumer plastics.

Most innovations so far have been pioneered by small entrepreneurs and community recycling programs in the United States, with considerably more advanced developments occurring in Europe. Meanwhile, the major U.S. plastics industries—the petrochemical companies, resin producers, packaging manufacturers, and the consumer-product giants that use plastic packaging—have yet to accept responsibility for their share of the waste-disposal problem. It is time that they applied their prodigious resources towards the research and development needed to make plastic recycling happen on a large scale.

This study found many questions still to be answered, but also encouraging signs that most of the components of a closed loop recycling system are available and ready for implementation. The roadmap that follows in Part II shows how concentrated efforts by government, business and civic leaders can bring about a fundamental change in the way Americans deal with plastic waste.

## 2. A GUIDE TO RESINS

### Plastics Are Products of the Lab

Plastics are man-made materials derived from petroleum or natural gas. They consist of various combinations of carbon with hydrogen, oxygen, nitrogen and other organic and inorganic elements formed by linking together small molecule groups called *monomers* into long-chain molecules called *polymers.*

Moldability is the chief characteristic accounting for plastics' high versatility. While in liquid form, plastics are capable of being molded, extruded, cast, or otherwise fabricated into myriad shapes. The properties of plastics can be widely varied by manipulating molecular structure, by using additives or blends, and by using ever-more sophisticated molding technologies. There are many excellent references on how plastics are made, structure of the industry, and the environmental impact of plastics production [14].

All plastics are either thermosets or thermoplastics. *Thermosets*, or duroplastics, are cross-linked polymer chains which harden permanently in the presence of heat and cannot be remelted, making them unlikely candidates for recycling. Thermosets make up approximately 13 percent of the U.S. plastic sales [15].

*Thermoplastics* are single-chain polymers which harden when cooled but, at varying temperatures according to resin type, will soften and can be remolded. This characteristic qualifies thermoplastics for recycling, though repeated melting and remolding of some resins will eventually downgrade material properties such as flexibility and strength. Thermoplastics represent about 87 percent of U.S. plastic sales [15].

This project focused on the thermoplastic resin types most commonly used in the United States and most prevalent in the waste stream. These are:

- high density polytheylene (HDPE);
- low density polyethylene (LDPE);
- polypropylene (PP);
- polystyrene (PS);
- polyvinyl chloride (PVC); and
- polyethylene terephthalate (PET).

## Some Resins Are Easy to Recognize

Citizens come in contact with most resins every day, and with practice, distinctions between some plastic types can be made. Techniques used by the plastics industry can aid identification. However, the presence of some look-alike resins rules out reliance on citizens for resin sorting. Hopefully, a voluntary coding system proposed by the Society of the Plastics Industry will help solve this problem.

The most widely used polymer in the United States, *polyethylene* is termed one of the "commodity" plastics because of its high versatility and relatively low price. The two most common types are high density polyethylene (*HDPE*), used for the majority of rigid containers such as dairy, detergent, and cosmetic bottles, antifreeze containers, and motor oil "cans"; and low density polyethylene (*LDPE*), mainly used for films such as trash bags, grocery sacks, and dry-cleaning bags.

There is some cross-over in applications between HDPE and LDPE. For instance, some films and closures are made of HDPE and some rigid items of LDPE. The difference between the two is the degree of branching of the molecular chains and the temperatures at which they melt. While most polyethylenes are used in products with a life span of under one year, more durable uses include toys, buckets, drums, pallets and automotive parts. Two other polyethylene films seeing increasing use are linear low density polyethylene (LLDPE) and ultra low density polyethylene (ULDPE).

Different grades of HDPE are suited to various molding techniques according to their molecular weight and melt-flow index, i.e., whether they are runny or stiff when passed through a molding orifice. In the recycling context, the grades most often cited are "high load HDPE" suited for extruded and/or blow-molded sturdy items like drums; fractional-melt HDPE used for blow-molding milk jugs and other bottles; and injection-grade HDPE for less demanding uses such as soft drink bottle base cups.

Together with polypropylene, polyethylenes are referred to by the generic term *polyolefins*. Olefins are chemically active hydrocarbons (i.e., ethylene and propylene) which are the building blocks of polymers.

*Polypropylene (PP)* is another commodity thermoplastic which has mainly been used for durable items like battery cases, furniture and conduit. It is seeing increased use in fibers for rope and strapping, and is making packaging inroads in both film and rigid form. Many cellophane-like snack food and candy wrappers are now polypropylene. Also "barrier" packaging, the best known example being the multi-layer squeezable ketchup bottle, uses PP in several of its six or seven layers of plastic and adhesives. The plastic linings of disposable diapers are also PP.

Polypropylene is increasingly interchanged for other members of the polyolefin group, as well as other resin types. For instance, while most carry-out plastic utensils are made of "high-impact" polystyrene, other cutlery that looks and feels just the same is now made of polypropylene [16]. This is one example highlighting the difficulty of sorting resin types simply by sight or touch.

*Polystyrene (PS)* is best known in its foamed form, some of which is made under the trademark name of Styrofoam. It is actually a family of plastics that takes a variety of forms:

- *high-impact* – rigid items such as plastic cutlery, disposable razors, prescription and vitamin bottles;
- *semi-rigid* – slightly pliable items such as lids, single service mini-containers for cream, jelly, and butter pats, and dairy tubs;
- *oriented or "crystal"* – clear deli carry-out containers, cookie package trays and some cellophane-like films; or
- *expanded or foamed* – used for packing and insulation materials, as well as food trays, egg cartons, and carry-out containers such as hot cups, plates, and "clamshells" for hamburgers.

One other member of the styrene family deserves mention if only because it is a fixture in virtually every home and office. This is a high durability plastic-rubber blend called *acrylonitrile butadiene* styrene, or ABS: it is best known as the sturdy housing of telephones and the plastic of Lego toy blocks.

*Polyvinyl chloride (PCV)* is one of the most versatile plastics because its inherent tough, shell-like quality can be softened and modified for diverse applications by the use of additives called "plasticizers." PVC's widest use is in durable construction products such as pipes, siding, conduits, cables, and gutters.

Known by lay persons as "vinyl," it is also used extensively in flooring, paneling, siding and as a leather or rubber substitute for luggage, footwear, upholstery, brief cases, clothing, camping gear, and beach rafts.

A sister polymer to PVC is polyvinylidene chloride (PVDC), best known by the trade name "saran" as a packaging material. PVDC is the shrink-wrap label used on the newly introduced plastic softdrink can.

While most PVC used in the United States goes to durable products, about 25 percent goes to disposable items and food and non-food packaging [17]. Food packaging includes salad and vegetable oil bottles, wraps for meat, produce and cheese, bottles for some imported mineral waters, and bottle cap liners and can coatings.

*Polyethylene terephthalate (PET)* is the best known of the family of polyester plastics because of its extensive use since 1977 for 1-, 2-, and 3-litre soft drink bottles. It is also one of the few post-consumer plastics with a recycling track record, owing to beverage container laws in nine states. In 1987, 150 million pounds, or 20 percent, of plastic soda bottles were recycled, according to industry sources.

Most reclaimed PET goes to fiberfill for ski jackets, pillows, and sleeping bags, or to industrial strapping. Some industry analysts predict many new uses will soon be unveiled, noting that recycling laws in California, New Jersey, and Rhode Island have assured the "critical mass" of material supply to convince industry to develop more recycled PET products. Yet recovery is virtually nonexistent in nonlegislated states, and rumors persist that some recovered PET ends up in landfills for lack of a market. The National Association for Plastic Container Recovery (NAPCOR) has recently organized to boost recovery levels (see more under Markets).

Besides the plastic soda bottle, PET is penetrating other food package formats as bottles, jars, sheeting, or blister packs, and some precision applications such as appliance and auto parts. PET blends are also being used for microwaveable trays and films.

There are reports of refillable PET soda bottles being developed in both the United States and Europe. Coke-Germany has already test-marketed a "recycling friendly" PET bottle in which the aluminum cap and HDPE base cup were replaced with a PP or PE cap and PET base cup respectively, to simplify material reclamation. In a similar move, several U.S. companies have introduced the *petulated* PET bottle, also minus the HDPE base cap and extra recovery steps.

*Multi-layer and engineering plastics* are less common than the types above but have been increasing their market share rapidly. Multi-layer, or "barrier" plastics have made a strong entry into packaging applications in recent years. Some well known examples are squeezable bottles for ketchup and condiments, and an easy-pour, sturdy orange juice bottle recently introduced by a leading juice company. The combinations of five to seven layers in these containers take advantage of different plastics barrier properties to keep oxygen out, keep carbonation in, resist the acidic effects of contents like citrus juices, and enhance squeezability.

The containers combine various resins (PP, PVDC, LDPE, PS, and EVOH, or ethyl vinyl alcohol) with adhesives and regrind layers. The regrind layers made of in-plant scrap are sandwiched between virgin resin layers so as not to come in contact with food contents of the package. Using regrind is cited as an advantage of barrier packages because it reduces manufacturing wastes.

Barrier containers were developed to increase shelf-life of plastic-packaged products. Their competitiveness with glass and metal containers has improved. though glass and metal still have longer shelf-lives [1]. Industry observers are of divided opinion on barrier packaging's growth potential. Some assert it is unlimited, while others say its use has already peaked. Either way, these packages raise problems for plastic reycling, because they are permanently bonded plastic mixtures which cannot be separated into distinct resins, and therefore can only be utilized by mixed-plastic recycling technologies. Also, since they cannot easily be distinguished visually from single resin items, such as PVC or HDPE containers, multi-layer items will cause sorting difficulties and material losses at the household and MRF levels.

Engineering plastics can be loosely defined as high-performance hybrid plastics with highly specialized uses. Prices for engineering grades are quoted in dollars per pound rather than cents per pound for commodity plastics. Initially, engineering plastics were introduced to replace high-strength materials such as metals in automobiles and airplanes. A marked new trend is entry into packaging, especially heat resistant microwaveable and dual-ovenable trays, and fancy-shaped, colorful, eye-catching containers geared to consumer impulse buying. Such trends toward more expensive plastic materials are forecasted to double consumer spending by the year 2000, from 20 to 40 percent of the food packaging dollar [1].

Whether engineering plastics are a boon or bane for recycling remains to be seen. Some firms believe their high value will create and automatic incentive favoring source separation and recycling. Others suggest that difficulties distinguishing engineering plastics from each other or from commodity plastics will hamper recycling efforts.

## Foamed Polystyrene: Popular but Flawed

Millions of hurried hamburger eaters would probably rank insulated and disposable clamshell packaging made of polystyrene foam as one of the handiest inventions of modern times. Yet the product is inherently flawed. Not only is it difficult or impossible to recycle, the production process uses a factory-made gas that is steadily eroding the ozone layer of the Earth.

Foamed polystyrenes have come under attack because of recent scientific evidence linking depletion of the earth's protective ozone layer with chlorofluorocarbons (CFCs), a group to chemical blowing agents used to produce some brands of formed PS. While CFC's have, in fact, been proven to negatively impact the ozone layer [18], foam packaging reportedly accounts for only 3 percent of all CFC use in the United States [19]. The major uses of CFC's are as coolants (including freon) in air conditioners and refrigerators, blowing agents for polyurethane foam insulation, and various cleaning and sterilization processes in hospitals, industry, and agriculture.

In response to consumer pressure and proposed legislative bans, the foamed PS packaging industry asserts that conversion to CFC substitutes has been underway for several years [20]; DuPont, a major producer of CFC, announced in early 1988 a plan to begin phasing out its use. Steam and hydrocarbons are two substitutes already in limited use, and new blowing agent HCFC 22 (hydrochlorofluorocarbon) recently received Food and Drug Administration (FDA) clearance for food-contact applications [19]. The hydrogen in HCFC 22 is said to make the molecule highly unstable so that it breaks up before reaching and damaging the stratospheric ozone layer.

Other citations in the literature, however, suggest extensive leadtimes and toxicity testing before acceptable CFC substitutes will be available [21]. One challenge for industry will be finding low-priced substitutes allowing foamed PS to retain its cost advantage over alternative products, such as poly-coated paper items. Another is the need to confront polystyrene litter's well earned reputation as an eyesore on the American landscape. As Florida Senator George Kirkpatrick put it: "For a hamburger that lasts a few minutes, why do we need a package that lasts as long as the pyramids?" [22].

## PVC: How Safe Is It?

Much controversy has surrounded the use of PVC in food-contact applications. When liquor was packaged in PVC bottles in the late 1960s, it was found that vinyl chloride monomers, which are carcinogenic, leached from the containers into the liquor. Asserting that manufacturing techniques have now improved to the extent that this risk is held at safe levels, the PVC industry has petitioned FDA to allow increased use of PVC for food packages. Meanwhile, activist groups hold that the leaching risk is still significant, particularly when PVC is in contact with edible oils [23]. As yet, FDA has not made a final ruling on the issue.

A second major concern about PVC has been its burning behavior in refuse incinerators. It has been alleged that the chlorine in PVC sets up conditions for production of dioxin emissions, and that hydrochloric acid created while burning PVC causes excessive corrosion inside combustion chambers, leading to a less clean burn.

The Vinyl Institute, the PVC industry's trade association, recently sponsored extensive testing of both factors at the Vicon Incinerator in Pittsfield, Massachusetts. Waste samples containing no PVC, average PVC, and extra PVC were burned under various combustion scenarios using state-of-the-art pollution controls. No significant changes in dioxin levels were observed with any of the samples, as long as the facility functioned at optimum temperatures. However, at suboptimum temperatures, dioxins did increase. Meanwhile, a direct correlation between PVC content of the waste and hydrochloric acid production was discerned, though this was reported to stay within the range of expected incinerator maintenance levels [24].

Several unresolved issues about PVC's impact on the waste disposal system still need attention. The caveat that PVC's burn safely in correctly run, modern incinerators, with state-of-the-art pollution controls, gives no assurance of PVC's behavior in the average incinerator. According to the U.S. Environmental Protection Agency, many facilities now operating in the United States do not meet all three conditions [25]. Finally, further research is needed on the effects of PVC plasticizers in both incinerators and landfills.

## 3. HOW MUCH PLASTIC?

### Data Provide Estimates of Quantities

The study of garbage is not an exact science. Waste streams vary by season, locale, weather on a given day, consumer whim. Methodologies vary. And the plastics industry is continually changing, particularly in the packaging area, where plastics are rapidly displacing traditional materials including paper labels and boxes, glass jars, and metal cans. Industry growth, meanwhile, has already outpaced projections made just two years ago.

A sampling of Massachusetts waste was beyond the scope of this study, but from available sources it was possible to extrapolate conservative and mid-range estimates of available materials, along with other important data on plastic volume, product mix, resin mix, and long-term availability. The numbers show that material supply is more than ample to support an aggressive recycling program and that the most plentiful resins are those that can become feedstock for existing plastic recycling technologies.

### Every Year, 190 Pounds Per Person

In 1985, the average American purchased and used 190 pounds of durable and non-durable plastic products. At projected industry growth rates, this figure will go to 258 pounds in 1995 and 301 pounds in the year 2000 [1]. Thus, Massachusetts' population of six million people will purchase and use over 1.5 billion pounds of plastic products in 1995, and 1.8 billion pounds in 2000. (See Table 2 for a comparison of plastic consumption by major countries.)

Due to varying product life spans, pounds of plastic consumed do not equal pounds thrown away the same year. For instance, plastic packaging may have a useful life of a few minutes or a few months, while plastics used in automobiles or construction may not reach the waste stream for two to twenty years.

### Plastics are 5 Percent to 9 Percent of Waste Load

The amount of plastic that ends up in the waste stream ranges from just under 6 percent to over 9 percent. Samplings done in various locales indicate basic trends (see Table 3).

Extrapolating from the North American figures and adjusting for plastic consumption growth rates suggests that plastics are currently 7 to 8 percent of

Table 2. Plastic Consumption by Major Countries (1985)

| *Country* | *Consumption (Pounds/Capita/Year)* |
|---|---|
| Spain | 64.9 |
| Netherlands | 80.3 |
| Britain | 100.8 |
| Norway[a] | 108.5 |
| France | 112.0 |
| Italy[a] | 121.0 |
| Canada | 146.7 |
| Japan | 150.3 |
| Switzerland | 170.3 |
| Denmark | 171.2 |
| United States | 190.1 |
| Australia | 196.0 |
| Sweden[a] | 202.4 |
| Finland[a] | 240.0 |
| Belgium | 244.4 |
| West Germany | 244.4 |

**Source:** Plastic Waste Management Institute [26].

[a] Figures are for 1984.

Table 3. Plastic Percent of MSW Weight

| *City or Region* | *Year* | *Percent Plastics* | *Source* |
|---|---|---|---|
| Essex, Hudson, and Union Counties, NJ | 1980 | 5.7 | [27] |
| Ann Arbor, MI | 1980 | 7.2 | [28] |
| Islip, NY | 1980 | 6.2 | [29] |
| Northeast Michigan | 1980 | 9.2 | [30] |
| Milwaukee, WI | 1981 | 5.7 | [31] |
| Central Wayne City, MI | 1981 | 6.2 | [28] |
| Ingham County, MI | 1981 | 6.9 | [28] |
| Kent County, MI | 1982 | 9.0 | [32] |
| Germany | 1983 | 7.6 | [33] |
| Belgium | 1983 | 5.0 | [33] |
| France | 1983 | 4.5 | [33] |
| Switzerland | 1983 | 7.0 | [33] |
| Atlantic City, NJ | 1984 | 9.5 | [34] |
| Netherlands | 1985 | 6.5 | [35] |
| Quebec | 1986 | 7.7 | [36] |
| Portland, OR | 1987 | 7.2 | [2] |

Table 4. Materials Discarded in Municipal Waste Stream (in millions of tons and percent)

| *Materials* | *1970* | | *1980* | | *2000* | |
|---|---|---|---|---|---|---|
| | *Tons* | *%* | *Tons* | *%* | *Tons* | *%* |
| Paper and Paperboard | 36.5 | 33.2 | 49.4 | 37.1 | 65.1 | 41.0 |
| Glass | 12.5 | 11.3 | 12.9 | 9.7 | 12.1 | 7.6 |
| Metals | 135.0 | 122.0 | 128.0 | 96.0 | 143.0 | 9.0 |
| Plastics | 3.0 | 2.7 | 9.6 | 7.2 | 15.5 | 9.8 |
| Rubber and Leather | 3.0 | 2.7 | 3.3 | 2.5 | 3.8 | 2.4 |
| Textiles | 2.2 | 2.0 | 2.8 | 2.1 | 3.5 | 2.2 |
| Wood | 4.0 | 3.6 | 5.1 | 3.8 | 6.1 | 3.8 |
| Other | — | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| Food Wastes | 12.7 | 11.5 | 10.8 | 8.1 | 10.8 | 6.8 |
| Yard Wastes | 21.0 | 19.0 | 23.8 | 17.9 | 24.4 | 15.3 |
| Misc. Inorganic Wastes | 1.8 | 1.6 | 2.4 | 1.8 | 3.1 | 2.0 |
| TOTAL | 110.3 | 100.0 | 133.0 | 100.0 | 158.8 | 100.0 |

**Source:** Franklin Associates [8].

MSW weight in Massachusetts. The team cross-checked this estimate against an analysis prepared by Franklin Associates for the U.S. EPA [8], which projected national average waste composition by analyzing production figures, imports and exports, and product life cycles. According to this model, the national plastic discard rate is estimated at 7.9 percent of MSW weight in 1988, and 9.8 percent by the year 2000. (See Table 4 and Figure 1.)

## Massachusetts Plastic Waste: 8 Percent

Using the 1988 figure of 7.9 percent as a baseline, two sets of forecasts were made. The conservative growth trend is based on Franklin Associates' national projections of post-consumer plastics to the year 2000. The mid-range trend represents a 3 percent annual increase over Franklin Associates' figures to account for observed higher than average plastic use in Massachusetts packaging formats, plus the fact that plastic industry sales have been 4 to 6 percent higher than expected since 1984.[2]

Table 5 shows the resulting range of post-consumer plastics potentially available for recycling from the residential waste stream. The higher figures are presented to allow planning flexibility. However, conclusions about plastic recycling capacity needed by the state are based on the conservative figures.

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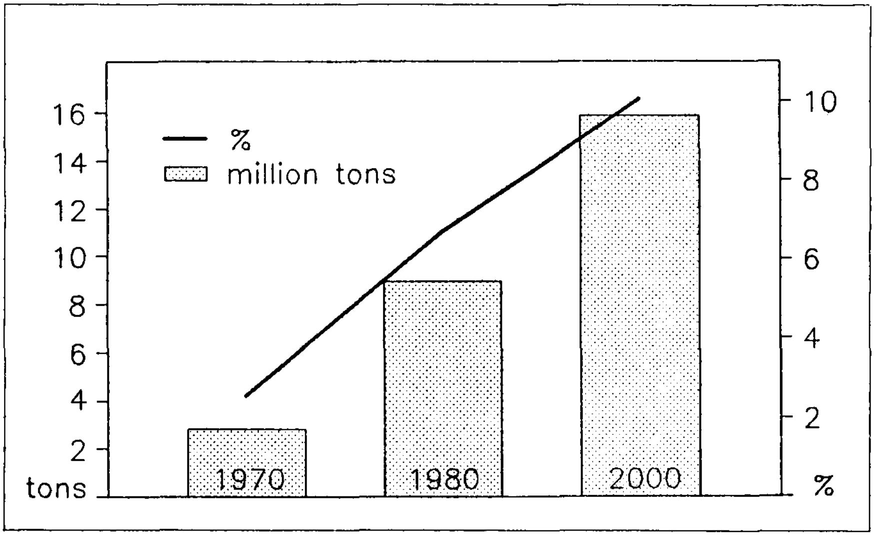
[2] Calculations by Massachusetts Division of Solid Waste Management based on Chem Systems projections [1], compared to industry growth rates [2, 3].



Source: Franklin Associates [8].

Figure 1. Estimated growth of plastic discards to 2000.

Table 5. Weight of Massachusetts Residential[a] Plastic Waste to 2000

| | *Conservative* | | *Mid-Range* | |
|---|---|---|---|---|
| *Year* | *%* | *TPY*[b] | *%* | *TPY* |
| 1988 | 7.9 | 237,000 | 7.9 | 237,000 |
| 1995 | 9.0 | 270,000 | 9.7 | 291,000 |
| 2000 | 9.8 | 294,000 | 11.3 | 339,000 |

[a] Residential waste is ½ ton per person per year according to MA. DSWM weight studies; to project residential plus commercial wastes, figures should be doubled to one ton/person/year.

[b] Tons per year.

## Plastics Volume is Three Times Its Weight

While much attention has focused on the weight of plastics in MSW, the concern for solid waste planners is *volume* of space plastics occupy in shrinking landfills. Various sources suggest that plastics, though 7 to 8 percent of MSW weight, are 25 to 30 percent of MSW volume [37, 38]. This is because items like plastic bottles are light and fluffy, and the material has a "memory," that is, a tendency to bounce back to its original shape.

The amount of landfill space plastics require is difficult to calculate because of limited data and wide variation in waste compaction methods at landfills. An uncompacted mix of heterogeneous plastic weighs thirty-eight to forty-nine pounds per cubic yard. Using landfill operator estimates that compaction would double or triple the pounds of plastic per yard, disposal capacity needs in the Commonwealth could run from 3 to 12 million cubic yards per year if all plastic is landfilled.

## Most Plastic Is Used Only Briefly

Product life cycle is a term used to refer to the period of time an item is retained and valued because it serves a purpose. The product becomes waste when its usefulness is perceived to have ended.

The time lag between product use and disposal varies widely, as Table 6 shows. Some items reach the waste stream in a few days or months and others aren't discarded for ten to twenty years. Thus, while packaging and disposable products may account for only 33 percent of production in a given year, they can account for 50 to 80 percent of waste stream plastics in that year. In contrast, the impact on the waste stream of long-life plastics such as construction materials is just beginning to be felt.

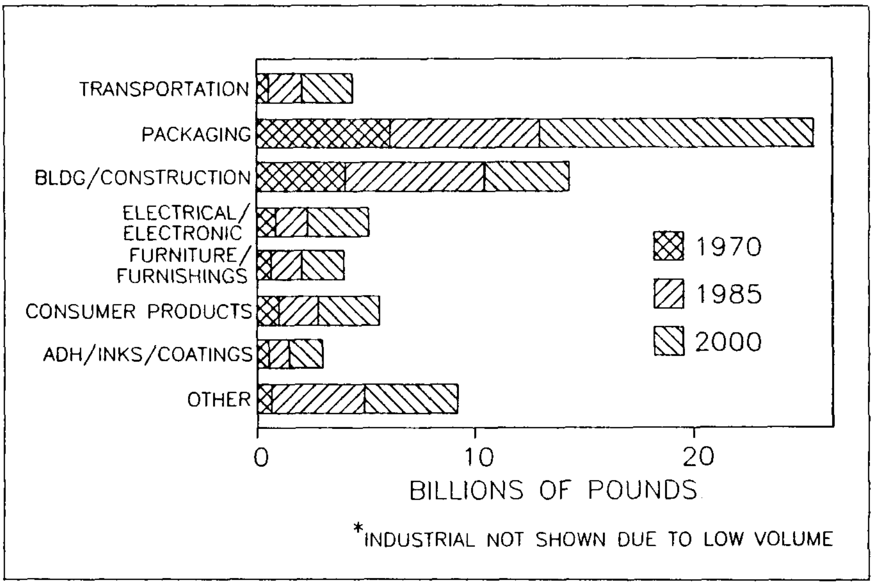
## Plastic Market Share to Increase

The recent *Plastics: A.D. 2000* study by Chem Systems, Inc. for the Society of the Plastics Industry predicts major growth for plastic use in both the most disposable and least disposable uses—packaging and building/construction materials, respectively [1]. Significant growth is also predicted in consumer/institutional, a category that includes many disposables such as carry-out

Table 6. Typical Life Cycles of Plastic Products

| *Product* | *Estimated Life (Years)* |
|---|---|
| Packaging | 1 or less |
| Disposable diapers | 1 or less |
| Pens, lighters, razors | 1 or less |
| Footwear | 2 |
| Apparel | 4 |
| Toys | 5 |
| Sporting goods | 7 |
| Luggage | 10 |
| Furniture | 10 |
| Wire and cable | 15 |
| Construction materials | 20 |

**Source:** J. Milgrom [29], Franklin Associates [8], and MA. DSWM.



*INDUSTRIAL NOT SHOWN DUE TO LOW VOLUME

**Source:** Chem Systems, Inc., 1987 [1].

Figure 2. Plastics growth by market, 1970-2000.

containers, health supplies, etc. Figure 2 from that study pictures comparative growth areas.

It is instructive to look behind the Chem Systems projections to grasp the full impacts of plastics growth on waste management and recycling systems. Table 7 presents Chem Systems' data on percent of resin use by each market. Table 8 translates these figures into quantitues of resin (in billion pounds) used or expected to be used by each market in 1970, 1985, and 2000.

Pursuing this analysis further, it is possible to derive cumulative estimates of total resin use in each market for the entire fifteen-year period from 1985 to 2000. For example, if Chem Systems' forecasts prove correct, selected markets' total resin use will be as shown in Table 9.

These are national figures projected over a time span during which various factors could alter plastic industry growth. Yet the packaging estimates alone present a sobering picture, as these items are essentially guaranteed to become waste immediately. The projected national total of 143 million tons of plastic packaging is equivalent to the total amount of MSW Massachusetts would generate in twenty-four years. Or, on a per capita basis, Massachusetts' waste management and recycling systems would need to absorb about 2.5 million tons of plastic packaging between now and 2000, or 166,700 tons per year. This does not take into account the phased arrival of longer life plastic items in the waste stream. However, it further corroborates that packaging alone will average about 70 percent of plastic discards in Massachusetts.

Table 7. Projected Market Distribution of Plastics

| | *Percent of Annual Production* | | |
|---|---|---|---|
| *Market*[a] | *1970* | *1985* | *2000* |
| Adhesvies, Inks, Coatings | 8.2 | 5.7 | 5.0 |
| Building and Construction | 22.7 | 23.6 | 21.3 |
| Consumer/Institutional | 11.3 | 8.5 | 8.1 |
| Electrical/Electronic | 10.1 | 6.7 | 7.1 |
| Furniture/Furnishings | 7.0 | 6.0 | 5.8 |
| Industrial | 1.0 | 1.3 | 1.4 |
| Packaging | 26.1 | 30.1 | 32.1 |
| Transportation | 5.8 | 5.3 | 6.1 |
| Other | 7.8 | 12.8 | 13.1 |
| Total Percent | 100.0 | 100.0 | 100.0 |

**Source:** Chem Systems, Inc. [1].

[a] See Appendix B for definitions of products in market categories.

Table 8. Projected Quantities of Resin Use by Market

| | *Annual Quantities (in billion pounds)* | | |
|---|---|---|---|
| *Market* | *1970* | *1985* | *2000* |
| Adhesives, Inks, Coatings | 1.475 | 2.525 | 3.585 |
| Building and Construction | 4.095 | 10.350 | 14.975 |
| Consumer/Institutional | 2.030 | 3.715 | 5.670 |
| Electrical/Electronic | 1.825 | 2.930 | 5.020 |
| Furniture/Furnishings | 1.275 | 2.635 | 4.100 |
| Industrial | 0.185 | 0.575 | 0.960 |
| Packaging | 4.695 | 13.200 | 22.580 |
| Transportation | 1.035 | 2.365 | 4.240 |
| Other | 1.400 | 5.600 | 9.260 |
| Totals | 18.015 | 43.895 | 70.390 |

**Source:** Calculations by MA. DSWM; data Chem Systems, Inc. [1].

Table 9. Cumulative Resin Use in Selected Markets, 1985-2000

| | *Billion Pounds* | *Million Tons* |
|---|---|---|
| Packaging | 286.2 | 143.1 |
| Consumer/Institutional | 75.0 | 37.5 |
| Building/Construction | 202.6 | 101.3 |

## Films, Rigid Plastics Are 83 Percent of Discards

Product form also has bearing on plastics targeted for recycling. Focusing on short-life products, mainly packaging, that will be in plentiful supply, the chief forms are rigid, film, and foam. These classifications are as important to the selection of collection and recycling technologies as the resin composition of MSW plastics.

A 1986 waste stream sampling by Recuperbec analyzed plastic discards by product form for the thirteen municipalities of the Quebec Urban Community (CUQ). Table 10 presents the CUQ breakdown of rigid, film, and foam items, plus a separate category for plastic trash bags. The two categories most likely to be targeted for recycling–films and rigid plastics–totaled 83 percent of plastic discards.

## Resin Leaders: Polyolefins, Polystyrene

Few U.S. characterization studies have analyzed the resin make-up of MSW plastics. Studies done elsewhere show that polyolefins are far and away the most abundant resins, followed by polystyrene and polyvinyl chloride, as shown in Table 11.

The closest sampling to Massachusetts is the Quebec study cited in Table 11. The project team observed strong similarities between the two regions' plastics wastes, except for two key differences in packaging formats. The first is that PET bottles were in limited use in Quebec at the time of the study. In Massachusetts, PET has a 58 percent market share and is covered by the redemption system. However, an estimated 10 to 40 percent of PET bottles are not redeemed and enter the waste stream (see p. 232). Second, liquid dairy products sold in Quebec are packaged in sturdy plastic pouches rather than HDPE jugs. This would suggest heavier polyolefin weights in Massachusetts than in Quebec.

In the absence of actual composition figures for Massachusetts, the Quebec figures are close enough for current planning purposes. They indicate a more than adequate match between targeted material supplies and available plastic recycling technologies and markets. Table 12 shows the estimated resin composition of Massachusetts residential plastic discards to the year 2000.

Table 10. Weight of Waste Sampled and Plastic Fraction (KG)

| *Sample Size* | | *Type of Product* | | | | *Type of Plastics* | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Total Weight* | *Plastic Weight* | *Trash Bags* | *Films* | *Rigid Plastic* | *Foam* | *Poly-olefins* | *Poly-styrene* | *PVC* | *PET* | *Others* |
| 616 | 54.5 | 7.4 | 20.7 | 24.4 | 2.0 | 28.0 | 18.5 | 5.0 | .1 | 3.0 |
| 1263 | 83.3 | 10.0 | 32.7 | 35.9 | 4.7 | 53.1 | 24.8 | 2.5 | -.- | 2.9 |
| 753 | 69.6 | 8.3 | 25.5 | 33.5 | 2.3 | 50.3 | 15.3 | 1.3 | .2 | 2.5 |
| 969 | 81.1 | 8.5 | 36.4 | 31.5 | 4.7 | 44.1 | 16.8 | 16.4 | .1 | 3.7 |
| 688 | 59.5 | 7.0 | 25.2 | 23.9 | 3.2 | 31.3 | 25.7 | 1.9 | -.- | 0.6 |
| 797 | 44.8 | 5.4 | 20.2 | 16.4 | 2.8 | 29.8 | 13.9 | 0.6 | .1 | 0.4 |
| 392 | 39.6 | 3.2 | 24.4 | 11.7 | 0.3 | 36.9 | 1.1 | 0.8 | -.- | 0.8 |
| 469 | 27.8 | 3.2 | 9.9 | 13.6 | 1.1 | 16.4 | 8.9 | 0.7 | .1 | 1.7 |
| TOTALS BY WEIGHT | | | | | | | | | | |
| 5947 | 460.2 | 53.0 | 195.0 | 191.0 | 21.0 | 290.0 | 125.0 | 29.0 | -.- | 16.0 |
| TOTALS BY PERCENT | | | | | | | | | | |
| | 7.7 | 12.0 | 42.0 | 41.0 | 5.0 | 63.0 | 27.0 | 6.0 | — | 4.0 |

**Source:** Centre de Recherche Industrielle du Quebec [40].

Table 11. Weight Composition of MSW Plastics (Percent)

| *Type* | *France [41] (1983)* | *Japan [26] (1985)* | *FRG [42] (1983)* | *CUQ [40] (1986)* |
|---|---|---|---|---|
| Polyolefins (PE and PP) | 57.0 | 57.3 | 70.2 | 63.0 |
| Polystyrene | 19.0 | 25.9 | 15.3 | 27.0 |
| Polyvinyl Chloride | 21.0 | 13.8 | 11.7 | 6.0 |
| Others | 3.0 | 3.0 | 2.8 | 4.0 |

Table 12. Resin Composition of Massachusetts Residential Plastic Waste to 2000 (tons/year)

| *Year* | *Total* | *PO (63%)* | *PS (27%)* | *PVC (6%)* | *Other (4%)* |
|---|---|---|---|---|---|
| 1988 | 237,000 | 149,310 | 63,990 | 14,200 | 9,500 |
| 1995 | 270,000 | 170,100 | 72,900 | 16,200 | 10,800 |
| 2000 | 294,000 | 185,220 | 79,380 | 17,640 | 11,760 |

**Note:** See also Table 14 for further breakdown.

[a] Resin composition percentages are from CUQ study [40].

[b] Plastic percents of MSW are from Franklin Associates [8].

Table 13. Estimated Unredeemed PET in Massachusetts, 1987

| *Material Availability* | *Bottle Law Recovery Rate* | *Estimated Unredeemed PET*[a] *(in million pounds)* |
|---|---|---|
| Low | 93% | 2.59 |
| Medium | 80% | 7.40 |
| High | 60% | 14.80 |

[a] Whole-bottle weights, including weight of HDPE base cup which averages 25 percent of bottle weight.

## Some PET Escapes Redemption System

Despite the Massachusetts Bottle Bill, some 2.5 million to 14.8 million pounds of unredeemed PET soda bottles end up in the waste stream and could be available for recovery by the plastic recycling system. This level could very well increase once curbside collection is available statewide; many citizens may decide to forfeit deposits in favor of easy curbside pick-up. In any case, production-level quantities of PET are now and will be in the waste stream.

Industry estimates of PET soda bottle recovery rates under Massachusetts' Bottle Law vary widely. Sources have quoted recovery rates ranging from 60 percent [43] to 93.4 percent [44]. Incomplete reporting requirements under the Bottle Law make more precise figures difficult to ascertain, but the consensus of a dozen interviewees suggests high levels of at least 80 percent.

To estimate PET soft-drink bottles sold in Massachusetts, the project team used reported national 1987 PET soft-drink bottle sales of 740 million pounds [2], and adjusted according to Massachusetts' reported consumption of six pounds per capita, double the national average. This yielded an estimate of thirty-seven million pounds of PET bottles sold in the state in 1987. Table 13 shows the resulting range of unredeemed PET potentially available for recovery via the state recycling system.

## 18 Million Pounds of Dairy Bottles

According to HDPE, dairy sales for 1987 [2], corroborated by the Milk Market Administrator, consumption of milk jugs is three pounds per person per year in Massachusetts. This means an estimated 18 million pounds of HDPE dairy bottles entering the waste stream annually could potentially be diverted to recycling.

Table 14. Plastic Discards in Massachusetts, 1988-2000

| *Material/Source* | *Total Tons* | *Landfill Needs (cubic yards)* |
|---|---|---|
| Residential Plastics (Conservative) | 3.2 million | 43- 65 million |
| Residential Plastics (Mid-range) | 3.7 million | 50- 76 million |
| All MSW Plastics (Conservative) | 6.4 million | 86-130 million |
| All MSW Plastics (Mid-range) | 7.4 million | 100-152 million |

Table 15. Cumulative Potential Resin Quantities, 1988-2000

| | *Quantities Available (in billion pounds)* | |
|---|---|---|
| *Resin Types* | *Conservative* | *Mid-Range* |
| Polyolefins | 4.0006 | 4.658 |
| Polystyrene | 1.717 | 1.996 |
| Polyvinyl Chloride | .382 | .444 |
| PET[a] | .108 | .118 |
| Other | .162 | .177 |

[a] Based on estimates that 20 percent of PET is unredeemed.

## Enough Plastic to Fuel an Industry

Clearly material supply is the least of the problems in designing a post-consumer plastics recycling system. Estimates of cumulative quantities of plastics available up to the year 2000 range from a low-end estimate of 3.2 million tons to a high-end of 7.4 million tons, enough to sustain a whole new industry in Massachusetts. (See Table 14.)

Referring back to the coversative and mid-range projections shown in Table 6, the total quantity of post-consumer plastics entering Massachusetts *residential* waste stream from 1988 to 2000 could range from 3.2 to 3.7 million tons, or 6.4 to 7.4 billion pounds. Looking at *total* municipal solid waste from residential, commercial, and other sources, plastic discards would double to 6.4 to 7.4 million tons, or 12.8 to 14.8 billion pounds.

In terms of landfill needs, this total material volume could require 43 million to 152 million cubic yards of added disposal capacity. Even if waste-to-energy plants operating or soon to go on line were to reduce this need by 30 to 40 percent, heavy pressure on land disposal capacity will continue.

The figures in Table 15 represent the best estimate of the "universe" of post-consumer plastics which could be drawn into a state-fostered plastics recycling industry. The action plan (Part II) outlines targeted quantities which could realistically be *captured* by the state's regional programs.

## 4. COLLECTIONS

### Experience Is Best Teacher

North American and European recycling operations have a surprising level of experience with waste plastic collections, from ad lib efforts launched in the last two years to highly developed systems that have been running since the last seventies.

Plastic collections here are in their infancy compared to their European counterparts. Many questions remain unanswered. Yet there is a growing awareness in the United States and Canada that these questions can only be answered by launching pilot collections to learn from actual experience the daily rhythms of post-consumer plastics recovery. The pioneers in this area reason that the costs of conventional hauling/transfer/disposal methods are so high that the risks/costs of a new way of collecting plastics can't be much worse, and may be better. They further reason that multi-material scenarios allow revenues from a mix of commodities to buffer the costs of plastic collections.

Programs underway in West Germany and the Netherlands for six to ten years offer guidance and encouragement for these experiments. Standardized, large scale, multi-material programs, combined with well conceptualized sorting plant technologies, have debugged plastics recovery to a considerable degree, though refinements continue.

Forty-one plastic collection programs were examined: sixteen in North America by phone surveys and twenty-five West German and Dutch programs by literature search. Because of wide variations in program designs, markets, recordkeeping, and so on, it was not possible to derive standardized measures of recovery rates or collection costs for all programs. Indeed, no isolated costs for plastics were available, though results will soon be in for several pilots.

While the survey did not reveal a collection model tailor-made to fit Massachusetts' regional program, several curbsides come close and valuable information emerged showing a range of program features which could be adopted. The most important conclusion is that collection pilots should be launched immediately to fine-tune efficiences and test design options to suit various population densities and other variables in different parts of the commonwealth.

### Programs Range from Rural to Big City

The following program profiles are presented as examples of plastic collection efforts to date. No one program is considered the model for Massachusetts, but several contain important elements showing that workable systems are possible. Profiles are presented for the following regions.

- Charlotte, North Carolina
- East Greenwich, Rhode Island
- West German Green Bin System
- Modified Green Bin System
- Bronx 2000, New York
- Ville La Salle, Quebec
- Naperville, Illinois
- Columbia County, Wisconsin

## Charlotte, North Carolina: Extensive Testing

Phase I of a voluntary, multi-material curbside collection for Charlotte, North Carolina was launched by Mecklenburg County in February 1987. Including recovery of PET soft-drink bottles, the program started with one truck and 2,500 households, then grew to three trucks and 9,032 households in June. In early 1989, the program will go citywide (110,000 households) and include a material recovery facility (MRF) to sort and upgrade recyclables for market. Charlotte's trail-blazing program will be important to watch because of its similarities to the Massachusetts model.

With funding from Coca Cola USA and design assistance from Resource Integration Systems, the pilot includes extensive experimentation and evaluation of variables, such as participation and recovery rates, truck sorting/loading configurations, and set-out container capacity.

The program is based on the well-known "blue box model" first tried in Kitchener, Ontario. Dedicated three-compartment trucks (two 28-yard Belgian Standards and one 15-yard Evol Lodall) collect recyclables once per week on the same day as one of the twice-weekly trash pick-ups. Each household was supplied a 1.5 cubic foot, bright red set-out container. Citizens were asked to place co-mingled PET, cans, and glass bottles in the container and stack newspapers on top. The pilot phase tested two box-style containers and one bucket style, all with the same capacity.

Table 16 shows that projected annual recovery levels for 9,032 households (population~27,096) are 322 pounds per household.

Table 16. Projected Annual Recovery Rates, Charlotte, North Carolina

| *Materials* | *Projected Pounds/Household* | *Total Tons* |
|---|---|---|
| News | 268.0 | 1,210 |
| Glass | 47.0 | 212 |
| PET | 4.0 | 8 |
| Bi-metal | 0.7 | 3 |
| UBC | 2.2 | 10 |
| Totals | 321.9 | 1,453 |

**Source:** Mecklenberg County DPW and Resource *Integration Systems, Ltd.*

Participation records show that 35 to 40 percent of households set out materials in any given week, with overall participation at 80 percent. For participating households the rate of set-out varies by material:

92 percent set out news;
63 percent set out glass;
53 percent set out PET;
48 percent set out aluminum or bi-metal cans; and
6 percent set out non-targeted materials.

A post-start-up phone survey found that 81 percent of participants found the container size, at 1.5 cubic feet, sufficiently large for weekly pickups:

| *Time to Fill* | *Percent of Households* |
|---|---|
| Less than 1 week | 19 |
| 1 week | 40 |
| 1-2 weeks | 25 |
| More than 2 weeks | 14 |

The program also evaluated set-out container handling ease for the truck crews. Until the MRF is on-line, crews do a partial sort at the curb by placing newspaper bundles in one truck compartment and sorting cans, glass, and PET bottles into the other two compartments. Crews found that the shallower, wider boxes permitted faster, easier sorting than the deeper, narrower buckets. Also, the buckets proved top heavy and more likely to tip when full, plus more apt to blow over and roll away when empty.

Charlotte also evaluated three truck-loading configurations to determine which method of curbside sorting was most compatible with final processing. Currently a sorting line at the temporary facility manually color-sorts PET and glass and magnetically sorts cans.

| *Loading Method* | *Bin 1* | *Bin 2* | *Bin 3* |
|---|---|---|---|
| A | News only | Glass/PET | Aluminum, bi-metal |
| B | News only | Glass/cans | PET |
| C | News only | All others | All others |

Method B proved to be most compatible with the processing system for several reasons. The PET container mix in Charlotte is mainly three-litre bottles, which took up too much space on the sorting line, and sixteen-ounce bottles, which are indistinguishable from sixteen-ounce glass bottles except by picking them up and touching them. Segregating the PET volume before the sorting line expedited processing of all the container streams. Operators measured PET volume at 43 to 56 pounds per cubic yard.

Once the MRF is operational truck-side sorting will be simplified to method C above and collection times will decrease. Presently, truck-side sorting is thought

Table 17. Projected Recovery Rates for East Greenwich, Rhode Island with Comparison to Charlotte, North Carolina

| *Material* | *Pounds per Household* | *Projected Tons per Year* | *Percent Difference from Charlotte* |
|---|---|---|---|
| News | 384 | 389 | +43 |
| Glass | 140 | 142 | +198 |
| UBC | 7 | 7 | +218 |
| PET | 11 | 11 | +175 |
| HDPE Dairy Jugs | 7 | 7 | – |
| Non-targeted Plastics | 5 | 5 | – |
| Ferrous | 27 | 27 | – |
| Non-targeted Ferrous | 19 | 19 | – |
| Totals | 600 | 606 | – |

**Source:** Rhode Island Dept. of Environmental Management and RIS.

to be the reason that trucks are not filled to capacity in an eight-hour day. Until the MRF opens, the curbside area expands, and trucks are filled twice per day, it is too soon to determine the impact on truck capacity of including PET bottles in the curbside.

## East Greenwich, Rhode Island: Mandatory Recycling

Under the nation's first mandatory statewide recycling law, Rhode Island in October 1987 launched two multi-material curbside pilots in the planned phase-in of a Providence area recycling region and MRF expected to be on line by late 1988. Both pilots include collection of PET soft-drink bottles and HDPE dairy bottles. Preliminary findings reported here are for the East Greenwich pilot area of 2,025 households. Extrapolating from second month collection data, recovery rates per household and projected annualized tonnages are shown in Table 17.

The third column compares household recovery rates in East Greenwich to those in Charlotte, where the same program model has been fully on line for nine months. The higher Rhode Island rates may reflect the impact of mandatory versus voluntary recycling.

The plastic recovery figures in East Greenwich are in any case particularly interesting. PET numbers reflect this container's 58 percent market share in Rhode Island plus the absence of a competing Bottle Bill redemption system.

HDPE dairy jug figures come close to the annual three pounds per capita use of this container, which would total 8.7 pounds for an average household of 2.9 people.

Finally, the non-targeted plastics are an interesting signal of citizens' readiness to source separate plastics. This fraction consists largely of other HDPE containers (mainly water, juice and detergent bottles) plus miscellaneous PET and PVC containers. Though publicity very specifically targeted milk jugs and soda bottles only, many citizens voluntarily source separated other plastics, too.

Collection crews have not discouraged this behavior by screening out non-targeted plastics and leaving them behind in set-out containers. Though an effective form of public education, this would slow down the co-mingled truck loading rate. Using two-compartment 28-yard Jaeger-brand trucks, crews place news in one section and all other materials in the second.

Another point of interest in this new pilot is an experiment with set-out container size. While some households received the standard 1.5 cubic foot box, others received plastic 20-gallon drums. The latter proved to have ample capacity, but were too heavy for citizens to move to the curb and crews to safely load into the collection vehicle. Loading difficulty also increased as the truck filled. In contrast, the set-out box proved easier to manage and appears to have adequate storage capacity given weekly pick-ups.

Rhode Island DEM also reports interesting findings from a recent collection trial using the new Labrie automated top-loading recycling truck. The truck is fitted with hydraulically lifted, 1.5 cubic yard baskets on the side of the storage bins, allowing a low loading height to reduce crew efforts but full utilization of the storage bins' cubic capacity. Other trucks without the lifts cannot be filled beyond the point where operators can no longer lift material to the top of the pile; they head to the MRF with a good deal of dead-air space at the top of the bins. This truck's 31 cubic yard capacity is fully used, making its working capacity nearly double many other trucks. One disadvantage is that the side baskets make the truck wider than others and thus ill-suited for narrow streets in older areas of Eastern cities.

Presently, Rhode Island participants are not asked to remove lids or flatten plastic bottles. Though flattening might seem indicated if plastic volumes increase, or when curbside areas expand, the impact of this, or on-truck mechanical flattening, must be evaluated for comparibility with the Bezner-brand sorting system being installed in the MRF.

New England CRInc, the contracted operator for Rhode Island's first MRF, is operating a hand-sorting process for co-mingled materials at a temporary facility until the MRF comes on line. PET is sold to Wellman Industries and HDPE to Eaglebrook Plastics. Summarizing experience to date, Rhode Island DEM spokesperson Janet Keller said, "The pilots are the best thing we ever could have done to understand day-to-day recycling realities and to gain an accurate information base for planning."

## West Germany: Large Rolling Bins

West German curbside collections of co-mingled recyclables, including plastics, began about ten years ago. Now approximately five million people benefit from this service. Generally, participation and recovery rates are high, with many programs reporting at least 20 percent reduction of landfilled wastes.

The original model, called the green bin system, involved supplying each household with two 64-gallon plastic carts—a green one for dry wastes (mainly recyclables) and a gray one for wet wastes (organics). The intent was to divert wet wastes for composting and send the rest to landfills or incinerators.

Both carts were serviced on rotation by the same automatic loading packer trucks, with one operator. No new trucks were required and collection costs stayed about the same. The carts were leased to participating municipalities or directly to households at a rate comparable to yearly purchase of plastic trash bags.

Once the rough sort into dry/wet wastes was in place, it became clear that 70 percent of the dry stream was recyclable (paper, glass, metals, plastic and textiles). This led to design of semi-automated sorting plants to recover resources resources from the dry stream. Some six to ten sorting plant technologies have now reached third- or fourth-generation status due to rapid development and refinements in this area.

A program sponsored by equipment manufacturer Schaeffer in the Kleve District (population–11,000) provides data for a typical green bin system. Over a fifteen-month period, the following pounds per capita were recovered:

| | |
|---|---|
| Paper | 97.0 |
| Glass | 52.0 |
| Metal | 12.0 |
| Plastic | 5.5 |
| Textiles | 7.0 |
| Unclassified trash | 15.0 |
| Total | 188.5 |

This yielded a recycling diversion rate of 23 percent by weight, and an estimated 40 percent volume reduction [45].

Newer generations of the green vin system have since fine-tuned household source separation to eliminate non-recyclable dry wastes (shoes, carpets, etc.) from the sorting plants, and to upgrade compost and secondary material quality. Some examples of the modified green bin system are:

- *Method A* – one bin for mixed recyclables; one bin for compostables; one bin for the rest
- *Method B* – one bin for paper; one bin for glass and metal; one bin for "wet" wastes; one plastic bag for plastics
- *Method C* – Same as Method B with addition of five-gallon baskets for household pre-sorting

- *Method D* – Sack and Sack Systems using various numbers of plastic bags according to the number of targeted materials, e.g., four sacks for paper, glass, "green" material (compostables), and the rest.

Another Schaeffer pilot in Burbach, FRG (population-14,000) using collection Method C yielded the following six-month recovery rates per residence (not per capita as above):

| | |
|---|---|
| Paper/Cardboard | 115 pounds |
| Glass/Metal | 33 pounds |
| Plastic | 6 pounds |
| Total | 154 pounds |

Together with heavily promoted backyard composting and waste reduction campaigns, Burbach's recycling program produced a 35 percent weight reduction in landfilled wastes according to solid waste surveys before and during the pilot phase [45].

The advantage of the original green bin system is that simple, user-friendly sorting increases participation. Also, the rolling carts are easy to handle, clean, provide greater storage capacity, permit collection of recyclables at frequencies of one week to one month, and perform well out-of-doors. The major drawbacks are storage space required for the carts, and downgrading of the paper fraction, if co-mingled with other materials. For instance, static cling of plastic bags to paper causes losses in both material fractions. Also, this premixing increases separation requirements at the sorting plants.

Modified green bin systems, such as the Burbach model including a separate plastic bag for mixed plastics, have improved material quality but also increased participation effort by citizens. This necessitated extensive public education or reeducation.

## Bronx 2000: A Plastic Buy-Back Center

Though not a curbside model, Bronx 2000's R2B2 buy-back program is included to give a fuller picture of rapidly developing plastic recycling opportunities. High redemption rates of materials such as aluminum cans under Massachusetts' bottle law tend to rule out the buy-back approach here. In contrast, lower redemption rates in metropolitan New York, plus waste diversion fees paid by the New York City Department of Sanitation and a large low-income population to collect the material, enabled R2B2 to coexist with that state's bottle law and expand its material repertoire to include many plastics.

The multi-material buy-back opened in March 1982, and began phasing in post-consumer plastics in March 1983. The first sales were contaminated color-mixed plastic bags of various resin types arising from the buy-back operation: the bags in which customers delivered various materials for sale. In the fall of

Table 18. R2B2 Buy-Back—Projected Annual Recovery

| *Material* | *Tons/Month* | *Projected Tons/Year* | *Percent of Total* |
|---|---|---|---|
| News | 250 | 3,000 | 26 |
| Glass | 529 | 6,344 | 56 |
| Corrugated | 78 | 940 | 8 |
| All Plastics | 40 | 484 | 4 |
| UBC | 28 | 332 | 3 |
| Bi-Metal | 9 | 110 | 1 |
| Wood | 16 | 196 | 2 |
| Totals | 950 | 11,406 | 100 |

1983 when New York's Bottle Bill took effect, R2B2 began buying PET, and has added other plastic grades since.

Focusing first on household post-consumer plastics delivered by individuals, R2B2 won a research grant and developed an in-house washing/shredding system to produce delabeled, clean polyethylene regrind. This positioned the company to open markets with local plastic molding companies, since, as Bronx 2000's Mike Schedler points out, "you can't sell materials that you don't have" [46]. Subsequently, R2B2 has added a number of commercial sources of cleaner, largely presorted plastics, such as cutlery and carry-out containers from delicatessens and film cans from photo labs. By cultivating both domestic and export markets, the company now says it can buy any kind of separated, identifiable plastics brought to the door.

R2B2 purchases plastics from individual collectors, commercial establishments, and seven other voluntary recycling programs. With no advertising to the general public, recovery has already reached forty tons per month. Shortly the program will expand into two adjacent buildings. R2B2 reports that 4,000 square feet is the minimal staging area required (storage space for pre- and post-processed materials) to adequately house the current plastics operation.

Based on recent six-month figures, Table 18 shows the R2B2's plastics volume exceeds that of used beverage cans.

For the same six-month period, plastic sales totaled $50,000, or an average of $200/ton, for the following breakdowns of plastics:

| *Resin* | *Tons* |
|---|---|
| Film (All Types) | 120 |
| HDPE (Various) | 50 |
| PET | 60 |
| PVC | 12 |
| Totals | 242 |

R2B2 sells film baled and all other plastics shredded in any quantity from one gaylord box to a 30,000-pound export container. Materials are acquired at 0 to 10 cents per pound and sold at 1.5 to 31 cents per pound. The encouraging news from R2B2 staff, and other sources, is that domestic and export markets are "running wild and expected to remain strong for several years" [46].

## Ville La Salle, Quebec: Films, Rigid Plastic

Ville La Salle, Quebec, launched a multi-material "blue box" curbside program for 20,000 households (50,000 population) in early 1987. To our knowledge, thisprogram is the only one in North America following the European example of collecting all types of plastic packaging, both films, and rigid containers.

The program experimented with both the 1.5 cubic foot box and larger set-out container sizes to accommodate the high volume of plastic packaging. Despite requests from many households for a second box, the program settled on one 1.5 cubic foot box to keep space needs down and handling ease up. The larger containers were ruled out after tests showed that elderly participants had difficulty carrying full containers on stairs.

The weekly service uses on-truck sorting into separate compartments for: newspaper, mixed paper, plastics, three colors of glass, cans, and refundable beverage containers. Thanks to extensive ongoing publicity and strong government support, plastic recovery levels started high and stayed high throughout the first year, averaging two metric tons per week. At first this material was stockpiled for lack of markets. However, a buyer recently surfaced with capabilities to sell all of this material to export.

The Ville La Salle program will be an important model for Massachusetts because of its similarities in collection model, targeted materials, and government-sponsored public education.

## Naperville, Illinois: Nine Materials Collected

The Naperville Area Recycling Center (NARC) in that suburb of Chicago added HDPE dairy bottles to its voluntary, multi-material curbside in spring 1987. Serving 13,000 households with a population of 45,000, the bi-monthly collection is financed by a $26 per ton diversion fee paid by the city (46% of revenues), material sales (41% of revenues), and miscellaneous income.

NARC targeted dairy bottles only, but also receives miscellaneous HDPE containers such as juice and detergent bottles. Though able to sell both types, the operation has not advertised for non-dairy bottles because, says NARC's Anne Aitchison, "the public would go bananas and overburden our existing space and equipment capacities" [47].

In the first eight months, NARC collected ten tons of HDPE, and sold it to Eaglebrook Plastids in Chicago at 10 cents per pound plus freight costs. The operators feel that adding milk jugs made no significant difference in collection costs since the curbside was already handling eight other materials. In fact, HDPE is their second most valuable commodity after aluminum cans.

NARC's curbside service is labor-intensive for both the public and staff. Citizens are asked to sort materials into nine categories and set them out in boxes, paper or plastic bags, or whatever is handy. NARC asks participants to remove lids and step on milk jugs to flatten them; over 50 percent of participants comply. Some participants set out milk jugs tied together with string, which makes them less apt to blow away, but also allows them to bounce back to their original shape. In constrast, bagged or boxed jugs tend to stay flattened.

Collections are done on a truck pulling one of two trailers in rotation. On the older trailer, which has six 4-cubic foot metal bins, heavy materials are sorted into the bins and the light HDPE and UBC are sorted into large plastic bags placed inside 35-gallon drums. The newer trailer was designed to carry six metal bins plus two baskets at the end for HDPE and UBC.

Collections are staffed by a driver and two loader/sorters. An average run covers 225 stops in three and one-half hours. The team's best rate for loading and on-truck sorting is eighty-five stops per hour, though the average is sixty stops per hour. Besides time consumed in material sorting, special for-fee pick-ups of appliances and other large scrap items are included in the rate. Noting that the load/sort method for eight material types was already "cumbersome," NARC concludes that adding milk jugs has not slowed the pick-up rate.

Generally, two trailer-loads are collected per day, four days per week, though an occasional extra run is needed on heavy days. The average take of HDPE bottles is seventy-five pounds per run. The mix of half flattened and half whole jugs fills one and one-half 35-gallon drums.

Jugs are transferred directly from the bags into a baler. Eight full bags make a 400- to 500-pound bale and the program produces three bales per week in the same industrial baler (32" x 60") used for corrugated and chipboard. Baling HDPE is less cumbersome than chipboard but more so than corrugated. NARC found the best way to produce a heavy HDPE bale that would not break apart was to wrap each bale with corrugated, compress for at least ten minutes, and tie with five wires to keep it from bursting.

In eight months of collection, milk jugs volumes have grown steadily to 1.5 tons per month. NARC plans to actively solicit other HDPE containers when space and equipment allow. Table 19 indicates NARC's annual recovery levels.

## Columbia County, Wisconsin: Curbside and Twenty-Two Drop-Offs

The Columbia County Recycling Program in Portage, Wisconsin, has been collecting post-consumer plastics in multi-material curbside and drop-off programs since January 1983. The bimonthly curbside for 2,800 homes in Portage plus twenty-two drop-offs in surrounding rural townships serve a

Table 19. NARC's Annual Recovery of Nine Materials

| *Material* | *Tons* | *Percent of Total* |
|---|---|---|
| News | 1,176 | 81.0 |
| Glass | 132 | 9.0 |
| UBC | 32 | 2.2 |
| Other Metals | 12 | 0.8 |
| Corrugated/Chipboard | 66 | 4.5 |
| Highgrade | 4 | 0.3 |
| HDPE | 10 | 0.7 |
| White Goods/Miscellaneous | 22 | 1.5 |
| Totals | 1,454 | 100.0 |

Table 20. CCRP Annual Recovery of Materials, 1987

| *Materials* | *Tons per Year* | *Percent of Total* | *Sales* |
|---|---|---|---|
| News Bedding | 596 | 26.0 | $ 18,800 |
| Loose News | 321 | 14.0 | 5,500 |
| Glass | 344 | 15.0 | 14,800 |
| Corrugated | 848 | 37.0 | 52,100 |
| UBC | 4.6 | 0.2 | 2,100 |
| HDPE | 48 | 2.0 | 6,100 |
| Tin | 73 | 3.0 | 700 |
| PET/Miscellaneous | 64 | 2.8 | ----- |
| Totals | 2,299 | 100.0 | $100,100 |

population totaling 27,000. CCRP collects PET, HDPE milk jugs, and other HDPE bottles. Table 20 shows annual recovery rates and earned revenues for all materials.

Like Bronx 2000, CCRP has observed the maturing and increasing competitiveness of secondary plastic markets. Last year, it had to manually de-lid bottles, sort milk jugs from colored HDPE, and bale the bottles to earn 6 cents per pound. Now it sells mixed and baled HDPE bottles to several Midwest buyers at a contracted price of 15 cents per pound, three times the price of a year ago. CCRP says revenues are well worth the marginal extra effort of collecting plastics.

## Key Findings: Plastics Worth the Effort

Most operators concurred that plastics were worth the added effort of collection because of their improving resale value. Also, they stressed the public's willingness to set out plastics. Several operators noted that adding plastics drew new participants into curbsides, because once citizens had this means of "relieving their guilt about throwing away bulky plastic bottles, they then started source separating other materials" [47]. Early results of pilots launched by the Center for Plastics Recycling Research at Rutgers corroborate this attitude.

Table 21 summarizes the programs on which the most data were available. In general, "user friendly" systems providing some combination of set-out containers, minimal material preparation requirements for citizens, good public education, frequent pick-ups, and a broad range of targeted plastics achieved the higher recovery rates. Properly conceptualized sorting operations or MRFs enhance material upgrading capabilities and market options.

Except for the green bin systems using packer trucks with partial compaction (to minimize glass breakage), no programs reported on-truck densification. The East Greenwich and Charlotte programs, in fact, have not yet reached the size where truck capacity is put to the test. But the sheer volume of plastics when collected in quantity indicates that extensive evaluation of vehicle sizes and experimentation with densification techniques are needed to develop optimum collection modes and economics.

Whereas collection capacity economics are not fully worked out, a wide range of off-the-shelf equipment is available to size-reduce plastics at the MRF for shipping to markets, and shipping costs of compacted plastics are comparable to those of other recyclable materials. Table 22 shows volume/weight figures for loose and densified plastics, as reported by surveyed programs.

It was not possible to determine plastics processing costs for MRFs or sorting plants as no such systems are yet on line in North America. Processing costs for pre-sorted plastics were also not available. However, sample figures from companies that provide reprocessing services are available from other studies [48].

The recommended collection approach for Massachusetts is to target a wide range of plastic packaging of all resin types—certainly all rigid containers and possibly film—to better capitalize on end-use technologies and markets. The optimum recovery method will likely be a hybrid utilizing vehicles that test out best in American pilots; addition of on-truck densification methods; and suitable match-ups of these systems with carefully designed MRF/sorting plant technologies.

Table 21. Comparison of Curbside Collection Programs

| *Locale/ Population* | *Collected Materials* | *Program Type* | *Annual Plastic Recovery, No./Household* | *Truck Type* | *Process* | *Markets* |
|---|---|---|---|---|---|---|
| Charlotte, NC (27,000) | news, glass, cans, PET | weekly curbside, 1.5 cu.ft. set-out containers, voluntary | 4 | dedicated 3-compartment, 1-man crew | semi-auto; sorting/ grinding. (MRF pending) | Wellman and others |
| E. Greenwich, RI (5,821) | news, glass, UBC, ferrous, PET, HDPE | weekly curbside 1.5 cu.ft. containers, mandatory | 23 | dedicated 3-compartment, 2-man crew | hard-sort/ baling. (MRF pending) | Wellman, Eaglebrook |
| Kleve, FRG (11,000) | paper, glass, metals, textiles, all plastics | curbside, alternate weeks, green bins, voluntary | 13 | standard auto-load packer, 1-man | sorting plant | NA |
| Burbach, FRG (14,000) | paper, corrug., glass, metal, all plastics | rotating curbside modified green bin, voluntary | 12 | standard auto-load packer, 1-man crew | sorting plant | NA |
| Naperville, IL (45,000) | multi-material & HDPE dairy | bi-monthly curbside, voluntary | 2.3 | recycling trailers, sort/ load, 2-man | baling | Eaglebrook |
| Bronx, NY (pop. NA) | multi-material & LDPE, HDPE, PS, PVC, PET & other plastics | buy-back & intermediate processor for other programs | NA | NA | washing, shredding & grinding or baling | molders, export, others |
| Columbia Cty., WI (27,000) | multi-material PET & HDPE | curbside & drop-off, voluntary | 4 | rebuilt beer truck, 3-man | baling | Midwest, Eaglebrook |
| LaSalle, Quebec (50,000) | multi-material, all film & rigid packaging | weekly curbside, 1.5 cu.ft. container, voluntary | 11.5 | dedicated 7-compartment truck | NA | reprocessor |

Table 22. Volume/Weight Ratios of Processed Plastics

| *Material* | *Condition* | *Weight and Volume* |
|---|---|---|
| PET soda bottles | whole, loose | 40–43#/cu.yd. |
| PET soda bottles | whole, loose | 53#/gaylord[a] |
| PET bottles | baled (30"x62") | 500#/bale |
| PET bottles | granulated | 700–750#/gaylord |
| PET bottles | granulated | 30,000#/semi-load |
| Film | baled (30x42x48) | 1,100#/bale |
| Film | baled | 44,000#/semi-load |
| HDPE (dairy only) | whole, loose | 24#/cu.yd. |
| HDPE (dairy only) | baled (32x60) | 400–500#/bale |
| HDPE (mixed) | baled (32x60) | 900#/bale |
| HDPE (mixed) | granulated | 800–1,000#/gaylord |
| HDPE (mixed) | granulated | 42,000#/semi-load |
| Mixed (PET and dairy) | whole, loose | 32#/cu.yd. average |
| Mixed (PET, dairy, and other rigid) | whole, loose | 38#/cu.yd. |
| Mixed (rigid, no film, or dairy) | whole, loose | 49#/cu.yd. |
| Mixed (rigid, oo film) | granulated | 500–1,000#/gaylord |
| Mixed (rigid and film) | densified by mixed-plastic molding technology | average 60#/cu.ft. |

**Source:** R2B2, NARC, Columbia County, Ville La Salle, IPCC, RIS, R.I. DEM.

[a] Gaylord size is the most commonly used: 40"x48"x36".

# 5. TECHNOLOGIES

## Existing Technologies Can Do the Job

A world-wide technology search to identify existing or promising plastics recycling technologies found two complementary methods that can handle the bulk of the Commonwealth's plastics waste stream. Several recent technology breakthroughs have brought methods well beyond the experimentation level, and industrial-scale operations in Europe have proven the engineering viability of various companies' technologies.

The new generation of post-consumer recycling technologies grew out of adaptations of off-the-shelf platic molding technologies and/or industrial scrap recycling technologies. The challenge has been to modify these technologies to accept heterogeneous mixtures of plastic resins, normally incompatible with one another, and to tolerate contamination by various non-plastic materials. Finely tuned systems set to precise tolerances and specialized resins had to be relaxed to accommodate random mixtures of post-consumer plastics.

The chief barriers to plastic recycling are in the nature of the material itself more than in the technologies. The key problem is plastics' susceptability to heat. High temperatures needed to fully sterilize the material will either degrade it or burn it. Therefore, recycled food-contact plastic packages cannot be guaranteed to meet FDA safety requirements and cannot be made back into food packages. This automatically rules out large product markets for recycled plastics, a hardship not faced by glass, metal, and some paper recycling processes. It does not, however, preclude significant boosts in use of reclaimed polyolefin pellets to make containers for products like motor oil, antifreeze, laundry detergents and other non-food items commonly packaged in plastic.

Another of the most promising recycling systems relies on techniques to blend resins that are usually incompatible with each other. These processes yield end products of relative thickness and mottled, dark colors, which limits their use to markets where durability and weatherability outweigh appearance.

The technologies can generally be divided into five broad categories:

- *separation technologies* that mechanically segregate distinct resins from a mixed-plastic stream;
- *mixed plastic technologies* that use the mixed-plastic stream as is;
- *PET recycling technologies* for soft-drink bottles only;
- *washing/upgrading technologies* for previously sorted plastics, such as HDPE dairy bottles; and
- *other technologies* now under development.

Forty technologies in these categories were surveyed. Attention then narrowed to those technologies most consistent with the multi-resin, user-friendly collection approach described in the previous chapter. PET recycling technologies were also given further evaluation because of sizable quantities possibly becoming available as the recycling program phases in. Also, PET's relatively high resale value justifies creating the capability at the MRF to cull this resin.

*Washing/upgrading technologies*, specifically those for previously source-separated HDPE rigid containers, were set aside at the outset of this study as being incompatible with the user-friendly, multi-resin approach. At that time, preparation requirements (lid and label removal, etc.) were deemed too demanding to generate high participation or justify sales revenues. However, a number of the firms using these technologies have since relaxed preparation requirements and substantially increased prices as systems, experience, and markets matured. Thus, these technologies may find a role in the early or later phases of the program, especially if the market situation remains as strong as at present. Several companies are leading the way on expansion of this market and are discussed in the Markets chapter.

## Rating the Technologies

Technologies were ranked for separation, mixed-plastic and PET applications, assigning scores based on the following criteria:

- *Feedstock versatility* – the capacity of a process to handle variations in the incoming material. The strictest requirement is for industrial, homogeneous, uncontaminated feedstock, e.g., thoroughly washed trimmings and/or clean floor sweepings. The most lenient and highest ranking feedstock is classified as post-consumer, heterogeneous (mixed), contaminated.
- *End products* – Quantity, quality, resale value, market potential for end products were the types of questions used to evaluate the various methods, although they varied somewhat depending on the type of technology.
- *Level of development* – For this criterion, the scale ranged from Drawing Board to Full Industrial Scale with one or more large plants in commercial operation.
- *Cost* – Costs were evaluated by determining how much a turn-key or ready-to-start plant using the technology would cost per 220 pounds of output per hour. Where not available, costs were estimated. The technology with the lowest cost automatically received the most points while the most expensive received none. All other technologies of the same type were scaled in a linear comparison to these two end points.
- *Productivity* – Each technology was assigned a number equal to its input capacity in pounds per hour divided by 220. The highest productivity received the maximum points for this criterion while the lowest received a proportional fraction of the maximum.

On the basis of these ratings, the team short-listed the top two or three technologies in each category as those the state should facilitate in the early phases of implementing the plastics recycling program.

## Separation Technologies

Separation technologies segregate high-value plastics from other plastics. The target plastic is generally the polyolefin fraction (HDPE, LDPE, PP). The machine takes a raw feedstock of mixed plastics that may be contaminated with paper, glass, metals, dirt, etc., and separates the plastics into polyolefin and a residue fraction made up of PS, PVC, and PET. It is possible to pelletize the polyolefin fraction (screening it in the process) to further ensure low levels of contamination. Usually the plastic is thoroughly washed at some stage.

Of the eleven technologies reviewed, three were most promising: *Transplastek* of Canada; *Sorema* of Italy; and *A.K.W.* of West Germany.

Transplastek's technology accommodates either mixed rigid plastics or films. The system involves chopping or granulating of the plastic followed by washing, sink/float separation and pelletizing the separated plastic. In the granulation phase, the raw plastic fraction of the MSW is chopped into small pieces which are then passed through an air cyclone to remove the fines (paper labels, dust, etc.). In the washing phase, dirt and other contaminants including other plastic resins are separated from the process stream. The plastic chips are sorted by a proprietary sink/float (separation) and drying system before being fed to an extruder for pelletizing. Once the pellets are formed, they are cooled and dried to produce the final end product that is ready for shipment as feedstock to make new products. It is also possible to sort out some of the more valuable types of plastics, like PET, after washing and before the plastics stream is made into pellets. This improves the overall economics of a plastic recycling program by allowing for the sale of an uncontaminated, high-value plastic fraction.

Sorema's methodology is similar to that of Transplastek. Sorema has used its technology for about twenty years, mainly on films (LDPE used in plastic bags and agricultural films used as a mulch and/or as hothouses). A full-scale test with Massachusetts MSW plastic would be needed to prove if this is a viable technology.

A.K.W.'s technology is quite similar to Transplastek's and Sorema's. A.K.W. also claims that it is able to convert the pellets into end products including plastic bags and blow-molded products. A.K.W.'s separation process is based on *hydrocycloning* rather than the sink/float/suction tanks used by Transplastek and Sorema. In hydrocycloning, the material enters the top of a cone-shaped vessel. There it encounters a very high speed vortex or swirl of water rising from the bottom of the vessel. The vortex spins the material around the cone in an extremely tight spiral as it is pulled down by gravity. The centripetal acceleration separates the material stream by density. The less dense material migrates towards the center of the vessel and is transported out of the top of the hydrocyclone. The denser fraction of the material leaves through the bottom.

All three of the technologies accept heterogeneous, contaminated feedstocks. This helps reduce handling/processing requirements at the household and MRF levels. All three systems produce lightly contaminated (95% PE, 5% PP), homogeneous pellets that are easily used by commodity custom molders.

A.K.W. has completed construction of its first industrial-scale plant, which is in shakedown and evaluation. Transplastek and Sorema already have industrial plants in operation. Sorema has longer experience in plant operation, but its system has primarily focused on agricultural films. Its full capabilities for post-consumer rigid plastics will need evaluation by way of an on-site plant audit.

Transplastek's system, while originally designed for mixed-industrial scrap, has been fully adapted for post-consumer mixed plastics. The firm also has extensive experience marketing PO pellets, particularly overseas, and its entire production is sold out. Transplastek's technology requires advance separation of films and rigid plastics, probably at the MRFs. The separation upgrades recycled pellet properties.

Plant costs are highest for A.K.W., while Sorema is slightly more expensive than Transplastek. All three systems process 2,000-2,200 pounds per hour, or approximately 17 million pounds per year. On the basis of cost, current development, and proven capability to accommodate MSW plastics, Transplastek was ranked first, Sorema second, and A.K.W. third.

Arrangements were made to run limited tests of the three short-listed technologies using representative samples of MSW mixed plastics. The project budget did not allow shipping large quantities, i.e., 500 to 2,000 pounds, so the companies' industrial scale, in-line systems could not be utilized for the tests. Instead, fifteen-pound samples were sent to each firm for testruns in their labs. The results give a fair indication of separation capabilities at this stage, and point to areas needing further development. The pellets produced by all three technologies were essentially identical in composition: 94 to 95 percent polyethylene and 5 to 6 percent polypropylene. Given the small sample size, it was not possible to detect statistically significant differences among the three systems' products.

The production tests have shown that all three technologies retrieve a polyolefin fraction of 64 to 80 percent of total feedstock. The remaining heavy plastics (PET, PVC, PS, ABS) account for 15 to 31 percent of the mix, while a 5 percent residue consists of fines, aluminum, paper labels, and other inorganics. The fines and heavy plastics are presently discarded as system waste while R&D efforts focus on further separating the heavy fraction into distinct resins for sale to market. Meanwhile, the parallel development of the recommended mixed-plastic technologies would provide an outlet for this sizable flow of inexpensive or free heavy plastics.

## Mixed-Plastics Technologies

Mixed-plastics technologies produce finished products molded from a mixed-plastic fraction. The feedstock can be random MSW plastics (generally about 63 percent polyolefins), or it can be made up of various recipes designed to achieve specific properties in end products. This includes the option to leave PET bottles and/or HDPE milk jugs in the mix or cull them out to be marketed separately. Process temperatures of 200 degrees Centigrade destroy most food and bacterial residues. Remaining contaminants and tramp materials are encapsulated in the blended plastic.

Of six technologies studies, two were retained for further consideration at this time: *Advanced Recycling Technology Ltd (ART)* of Belgium and *Recycloplast* of West Germany. A third promising technology, *Polymer Products* of Iowa, was not available for sale at the time of the survey and was therefore not included. It should be further evaluated along with a new, proprietary, mixed-plastic technology developed by Polymerix.

The Recycloplast process begins with the feedstock passing through a metal separator to a cutting mill, where it is shredded into flakes. From there, the plastic goes to a storage/feed silo. Several such silos fitted with values can create almost any desired recipe of plastic. The silos can be used for the introduction of film from agricultural sources and coloring agents and/or other chemical additives that enhance certain properties. The plastic is then fed into a cylindrical plasticizer which gently kneads the mixture into a homogeneous paste using the heat produced by internal friction. In this manner, the system avoids denaturing the plastic, which causes it to lose its essential properties.

Minimizing degradation of the plastic also reduces the amount of hydrochloric acid emmissions produced by the chlorine in PVC. To screen out this pollutant and acid rain precursor, Recycloplast has a complete flue gas treatment unit as part of its plant; extensive studies have shown it to be effective although quite costly (15 to 20% of plant capital cost) because it requires a biologically controlled filter.

On leaving the plasticizer, the flow of thoroughly mixed material is cut into portions dictated by the mold size. The portions are molded by hydraulic presses at 300 to 1,500 tons of pressure, then are quickly cooled to provide the finished product. Due to the relatively low structural strength of plastic, Recycloplast's end products tend to be thick-walled in nature: sheets, panels, skids, flower pots, cable reels, pallets.

Advanced Recycling Technology's ET/1 process uses a shredded feedstock that is partly densified film and partly mixed rigid plastics including HDPE. The method is similar to that of Recycloplast except in the plastification/molding phases. While Recycloplast uses a rotary cylinder to provide paste to a press-type molder in a two-stage process, the ET/1 combines these two steps into one by *extrusion molding*. The only difference here is that the plastic paste is held inside a mold to cool and solidify after it has been forced or extruded. The ET/1 uses an auger to friction heat the mixed plastic and feed it into the mold. Since this auger-to-mold connection is air-tight, no off-gassing is reported.

Ten or twelve molds are mounted on a rotary turret that looks something like a gattling gun. At any one time, seven or nine of the molds are under water while a cooled shape is being ejected from the last mold. The system produces products that are from one to four yards in length with cross sections up to four inches square. The ET/1 can be simultaneously fitted with up to twelve different mold shapes provided all molds are of the same length and the cross-sectional area varies by no more than a factor of two.

All impurities in the finished product are concentrated in the center of the shape. The final product can be nailed, screwed, sawed, planed, drilled, and painted just like wood. Dyes can also be added to the plastic to produce any fairly dark color. The method produces items that are quite long in comparison to their cross sections, making it ideal for products like lumber, fence posts, and sign posts.

Both technologies are currently operating on a large industrial scale. ART's ET/1 was the least expensive of all of the technologies reviewed in this category while Recycloplast was the most expensive, in part due to its flue gas control system and the expensive hydraulic presses used in the molding phase. The ET/1, however, is limited to about 400 pounds of through-put per hour, while

Recycloplast can produce up to 1,500 pounds/hour depending on the end product. To bring the ET/1 up to 1,200 pounds/hour, three molding units could be used, all supplied by the same preparation equipment and operated by the same staff.

The ET/1 method is simpler than Recycloplast and requires no off-gas control. Also, three facilities using the ET/1 technology are already on-line in the United States, though none are operating on full production schedules. One is at Processed Plastics in Ionia, Michigan, one at the Center for Plastics Recycling Research at Rutgers University in New Jersey, and the third is owned by New England CRInc. of Massachusetts. These working units will provide valuable information on how well the system performs under local market conditions. The Recycloplast and ET/1 technologies produce an end product whose appearance is somewhat rough and uneven in color, and each has limits in terms of product shape and size. For optimum market penetration a combination of the two technologies could be used to produce a wider range of end products.

## Pet Recycling Technologies

The PET soft-drink bottle is composed of many things: PET (clear or green), an HDPE base-cup, label, glue and aluminum cap and ring. All of these components, with the exception of the glue and label, have a high market value if they can be separated and recycled. Since up to fourteen million pounds of unredeemed PET could be available for recovery in Massachusetts, potential market value (at 20 to 30 cents per pound) ranges from $2.8 million to $4.2 million per year.

PET recycling involves shredding the feedstock, followed by washing and contaminant removal. Optional additions in some technologies include color separation of the clean PET, pelletizing the flakes, and increasing intrinsic viscosity to add value.

Four technologies of varying uses and performance were chosen: *Wellman* of South Carolina, *St. Jude Polymer* of Pennsylvania, *Nelmor* of Massachusetts, and *A.K. W.* of Birmingham, United Kingdom. Because it was not possible to make an on-site audit of A.K.W.'s apparently promising technology, the system was set aside for future consideration after an audit has been conducted.

Wellman is the largest U.S. user of recycled PET from deposit states, with consumption for 1986 estimated at 100 million pounds. Its technology is not available for other users and few details of the proprietary process are known. The company produces fiberfill from the plastic using a technology that is also well developed in Europe.

St. Jude Polymer, in close cooperation with Lummus Co. of Columbus, Georgia, has expanded processing operations to roughly 22 million pounds of PET per year. Projections for 1988 call for a capacity of between 50 and 60 million pounds, depending on site acquisition. Details of the process are confidential. St. Jude can apply solid-state technology to increase the viscosity of its product to between 0.8 and 1.4, thus enhancing its use in more demanding applications.

Nelmor aims to produce a very clean PET flake that could be reused without going to the extrusion/pelletization step, thus avoiding thermal degradation. This approach is not common now because aluminum contaminants could create severe problems in molding processes. Nelmor has developed pilot-scale components, but does not have a commercial process on-line.

An in-depth comparison is not possible due to the proprietary nature of much of the technology. Should a decision be made to actively encourage plant installation, however, these three front-runners, plus A.K.W., should be evaluated more fully.

## Other Technology Developments

A number of promising technology developments came to light during the course of this project. It was beyond the project scope to evaluate these leads, so no assertions are made as to the soundness or commercial readiness of these methods.

*Plastic-coated paper recycling* – The problems cited earlier about foamed polystyrene carry-out containers have spurred various claims and counterclaims about the relative recyclability or degradability of plastic-coated paper versus foamed PS items (cups, plates, etc.). On the degradability question there is almost no up-to-date research to back up claims for or against either type of package. Thorough research is needed to create a basis for objective discussion. Similarly, the recyclability question is somewhat clouded. Technically, foamed PS can be recycled. Though this is not widely practiced, several firms have reported research and development in progress.

Six technologies in various stages of development are currently capable of recycling plastic-coated paper items. These technologies target *poly-coated papers* typically used in such products as milk cartons, frozen food boxes, six-pack carriers, paper cups and plates, and so on. Two systems utilize only clean manufacturing wastes (trimmings, etc.); three utilize post-consumer feedstock; and a sixth technology, now moth-balled, utilized post-consumer poly-coated materials. Of the five operating systems, three are in industrial scale and two are pilot plants.

The technologies chiefly target the paper for recovery because it is bleached, long-fiber high grade material with excellent resale value. The polyethylene removal process automatically lifts off printing inks as well, leaving a high quality pulp substitute.

Two of the systems also reported capability to reclaim the polyethylene coating material. Four of the operating systems are pulping methods, and the fifth uses the poly-coated paper as is in various molded products. Two of the processes reportedly sterilize the recovered paper during the pulping stage so that it is free of organic residues and theoretically safe for reuse in food packaging.

These technologies merit watching for possible future use. However, the regional recycling program will not target poly-coated paper at this time.

*Degradable plastics* – The litter and marine-pollution problems noted earlier have prompted keen interest in the idea of degradable plastics that break down and go away over time. *Photodegradable* plastics are blended with additives that make the material degrade when exposed to the ultraviolet rays from sunlight. One type of the plastic has been used for a number of years for six-pack yokes, in response to legislation in about a dozen states. A photodegradable plastic trash bag made by a Massachusetts firm has been on the market for several years. Exposed to direct sunlight for a given period of time, these items over-heat, become brittle and break down into smaller and smaller pieces. *Biodegradable* plastics contain additives such as cornstarch, which make them susceptible to attack by microorganisms like those that decompose organic wastes in a landfill or compost pile. The additives are weak links in the plastic molecular chains; when microorganisms eat them the plastic falls apart.

A few new plastics under development are made completely of biodegradable organic material such as cornstarch or chitin, a protein derived from shellfish waste. However, most biodegradable plastics are blends of synthetic plastic and organic additives.

While it may prove appropriate to require certain highly litter-prone items to be degradable, the Society of the Plastics Industry warns that degradability alone is too simplistic a solution to the complex problem of plastics disposal [49]. Also, Research Triangle Institute, which is conducting a study of degradable plastics for the National Oceanic and Atmospheric Administration, cautions that long-term effects of plastic dust and other degradation by-products on the food chain and marine environment are as yet unknown [50]. Finally, wide use of degradables would be at cross-purposes to plastics recycling, which aims to convert plastic wastes to durable products and predictable raw materials.

*Plastics as fuel, chemical feedstock* – Various reports indicate development of technologies using pyrolysis, solvents, and other processes to reduce plastics to fuel products or to chemical feedstocks for new plastics. Most of these methods are experimental and five to fifteen years away from commercial availability. They bear watching, and could draw strong interest in the event of renewed petroleum shortages and price shocks.

## Conclusion: Build Two Plants

Massachusetts state government will encourage installation of at least one polyolefin separation plant and one mixed-plastics plant. Each plant should be supported with extensive market development assistance.

The need for a PET recycling plant is less pressing because the redemption system has maintained high recovery rates. However, the option should be reconsidered if convenient curbside collection diverts significant quantities of PET away from redemption.

Further evaluation will be done on washing/grinding systems for sorted plastics like HDPE milk jugs. The strong market conditions and rapidly evolving technologies indicate favorable economics for that portion of the plastics stream. The best route with this technology may be to use the Commonwealth's ample economic developments resources to attract an existing processor to Massachusetts.

## 6. MARKETS

### Diverse Markets Must Be In Place

When the flow of post-consumer plastic reaches production volumes in the early 1990s, a network of markets for the material must be in place. This preliminary market survey found that some markets for PET and HDPE regrind already exist and are growing rapidly. Others, like that for recycled polyolefin pellets, already show strong growth and have huge potential if major customer firms begin specifying recycled feedstock as a preferred material. A third category of markets, those for finished lumber-like products made from mixed plastic, will have to be developed from scratch, but government procurement programs could play an important role in getting them started.

### Polyolefin: Local Market Is Shifting

Using the recycled polyolefin pellets from the separation technology tests, thirty-seven custom molders in Massachusetts were surveyed to assess their readiness to use this feedstock. The Society of the Plastics Industry lists 959 plastic manufacturing and related member companies in Massachusetts, of which the thirty-seven were selected because their high production volumes suggested they were buyers of commodity plastics. The companies could theoretically realize a significant profit advantage because recycled PO pellets are priced about 50 percent below virgin resins.

The company purchasing agents were contacted and sent a molded test piece, a one ounce sample of PO pellets, and a product specification sheet. The project budget did not permit sending sufficient pellet quantities for in-plant testruns, which require a minimum of 500 pounds.

Though too limited for hard conclusions, the survey did reveal two key trends about the local plastics industry. First, many Massachusetts custom-molders are already shifting away from commodity plastics to high specification, high-value-added items made of specialty and engineering plastics. Second, large custom molders seldom have leeway to deviate from their customers' product specifications of color, raw material, and so on. Therefore, it is the *customer* companies that will have to be persuaded to accept reclaimed plastics. A large motor oil or liquid detergent producer, for example, could significantly bolster the market by switching to PO pellets for injection or blow-molded bottles. The move could also provide excellent public relations mileage for the company if it is the first major user of the state's recycled pellets.

Discussions with plastic brokers and reprocessors, combined with the experience of Bronx 2000 (see Collections section), suggest that small local custom molders and plastic industries in developing countries offer the greatest market potential for PO pellets. They are less able to compete on world markets for virgin resin feedstocks; they often use older, less sophisticated and more tolerant molding equipment; and their product lines tend more toward functional essentials than high-tech items like microwaveable trays. The current worldwide polyethylene shortage, discussed later in this section, bodes well for the PO pellet market.

## Mixed Plastics: Park Benches of Future

Market potential was analyzed for nine mixed-plastic products which could be produced by ART's ET/1 technology, and estimates were made of New England market size for the three most promising products. The data show that these markets, if properly developed, could support a minimum of two ET/1 units and a maximum of four ET/1 plants of three units each. (See Table 23.)

Boat docks, horse stalls and park benches offer the largest porential for initial marketing efforts. These products capitalize on plastic's resistance to weather, chemicals, salt water, temperature extremes, termites, and ultraviolet light deterioration.

Executive Order 279, signed by Governor Dukakis in May 1988, established a state procurement program for recycled content products [51]. This will help assure demand for items like park benches and docks, both of which are cost competitive with wood and concrete. The Massachusetts Division of Waterways is particularly interested in plastic pier decking because of high wood replacement costs.

The large horse population in New England and New York presents the opportunity to replace the top and two bottom horse stall boards, which are most subject to wear and tear. This is a potentially high demand area, provided the horse industry, steeped in tradition, will accept an alternate material. (See Table 24.)

## Tough Competition: Wood

While the uses for mixed-plastic lumber are limited only by the imagination, the immediate need is to identify likely market niches and develop them aggressively. The main hurdles are that plastic lumber is not suited for structurally demanding uses, is not yet accepted by consumers, and may not be cost-competitive with wood except in applications involving high maintenance and/or frequent replacement.

Structural tests have shown that lumber made of the average mix of MSW plastics may not offer sufficient strength to compete with low-priced framing

Table 23. Market Prospects for Various Mixed-Plastic Products

| *Market* | *Key Considerations* | *Conclusions* |
|---|---|---|
| Boat Docks | Extremely large existing market in NE.<br>Continuous exposure to harsh, wet environment.<br>Plastic products currently used, accepted. | Strong potential. |
| Auto Curb Stops | Plastic currently used, cost effective.<br>Coloring throughout saves maintenance costs.<br>Lighter weight saves on labor costs. | Limited data available. |
| Breakwaters | Wet environment ideal for plastic. | Tight construction regulations; no large NE market. |
| Park Benches | Continued exposure to inclement weather.<br>Primary customers are governments, schools. | Strong potential. |
| Mushroom Trays | Moist conditions require plastic.<br>Plastic products currently used. | Limited market data available; possible food-contact concerns. |
| Horse Stalls | Horses tend to chew top rail, forcing replacement.<br>Bottom of stalls deteriorate, forcing replacement.<br>Large market also in New York. | Strong potential. |
| Picnic Tables | Manufacturing for government use done by prison system with subsidized lumber.<br>Outdoor environment ideal for plastic. | Small market; price supports rule out competitive position. |
| Playground Equipment | Outdoor environment ideal for plastic. | Limited market data available. |
| Railroad Ties | Excellent potential for recycled plastic.<br>Potentially large replacement market. | Tight construction specs.<br>Long-term strength and load-test results pending. |

**Source:** Touche Ross, Inc., 1987.

lumber made of wood. This is particularly true if only initial purchase price rather than life-cycle costs are considered.

Table 25 shows that plastic's E-value, or relative stiffness, is considerably lower than that of common pine; plastic lumber will thus require tighter spacing of underlying joists (of wood or steel) to avoid excessive springiness. Careful product engineering and market targeting can somewhat offset this disadvantage. Flexibility is no problem, for instance, in rails for horse stalls, and an all-plastic park bench could have stiffness designed in. Research and development might also find certain plastic recipes that bring the E-value closer to that of wood. Plastic lumber should also be specifically marketed as a non-toxic, long-life alternative to pressure-treated lumber, which contains cyanide, and products made with creosote.

Table 24. Market Sizing for Mixed-Plastic Lumber
(in thousands of pounds/year)

| *Market Capture[a] (Percent)* | *Horse Stalls[b]* | *Park Benches* | *Boat Docks* |
|---|---|---|---|
| 10 | 1400–1450 | — | 2000– 3150 |
| 20 | 2870–3050 | — | 4000– 6300 |
| 30 | 4275–4535 | 150–270 | 6000– 9400 |
| 40 | 5680–6025 | 240–360 | 8000–12600 |
| 50 | 7150–7580 | 300–450 | 10000–15750 |
| 60 | — | 360–540 | — |
| 70 | — | 420–630 | — |

**Source:** Touche Ross, Inc., 1987.

[a] Represents percent of current market that may be displaced by plastic product.

[b] Includes New York market.

Table 25. Structural Properties of Plastic vs. Wood Lumbers

| *Wood Type* | *Density (lb./cu.ft.)* | *Horizontal Shear (H) (psi)* | *Compression Perp to Grain (psi)* | *Compression Para to Grain (psi)* | *E-Value (Million psi)* |
|---|---|---|---|---|---|
| Common Lumbers | | | | | |
| Eastern White Pine | 24.9 | 120–145 | 600 | 950–1550 | 1.5 |
| Red Oak | 43.2 | 120–145 | 600 | 950–1550 | 1.5 |
| White Oak | 46.3 | — | — | — | — |
| Sugar Maple | 44.0 | — | — | — | — |
| Soft Maple | 35.0 | 95–110 | 365 | 900–1050 | — |
| White Fir | 27.0 | — | — | — | — |
| Common Dock Lumbers | | | | | |
| Lophira Alata | — | 120–150 | 390–455 | 875–2250 | 1.6–1.76 |
| Southern Yellow Pine | — | 95–145 | 380–455 | 1000–1750 | 1.6–1.76 |
| Douglass Fir | — | — | — | — | — |
| Plastic Lumber | 57.0 | — | 3500 | 3500 | 0.075 |

**Source:** Recourse Systems, Inc., "Feasibility Study for the Massachusetts Public Sector Procurement Program," internal document, MA. Division of Solid Waste, January 1988.

## Polyethylene: Upbeat Market

The recent surge in polyethylene markets, with prices for post-consumer material tripling in 1987 and those for virgin grades posting 22 percent increases in the last six months [52, 53], gives a strong indication that this of all the plastic sectors is the most likely to be market driven. Polyethylene, like polystyrene before it, could soon double its 1986 price level [54].

The worldwide polyethylene shortage is a result of rapidly growing demand combined with a lack of plant capacity to produce the ethylene monomers that are the raw material of polyethylene. Industry sources predict this shortfall could continue for two years or more [54, 55]. Because it takes three years to put an ethylene reactor on line and two more to commission a polyethylene plant, one forecaster suggested a lag of up to five years, though he still called the situation temporary [56]. Current ethylene capacity is sold out through 1990, but if several mothballed or pending plants open, the situation could change rapidly [54].

The lower value of the dollar has also drawn domestic polyethylene production to export markets, increasing supply pressures for domestic molders and boosting demand for reclaimed polyethylene. Record breaking 1987 demand for products like pipes, tiles and conduit, which can readily absorb high levels of post-consumer polyethylene, has also helpde fuel price increase [57].

## Two Companies Lead Market Surge

Two firms specializing in relcaimed polyethylenes are experiencing dynamic growth and leading the marketplace.

*Midwest Plastics* of Stoughton, Wisconsin, has developed a proprietary high-speed cleaning process that removes paper labels and contaminants from HDPE milk jugs and other containers. The system can process 2,000 pounds per hour to a Grade I regrind used as feedstock for drain pipes, culverts and tiles. Midwest manufactures these items itself and also supplies regrind to other producers. Material acceptance has been so strong that Midwest plans to open additional reprocessing plants on both coasts.

Midwest Plastics currently purchases all types of HDPE bottles mixed, at twenty-five cents per pound granulated, and fifteen to eighteen cents baled. The firm also has successfully tested a pilot-scale version of its system for mixed film and plans to expand this operation and begin purchasing film shortly. Midwest has encouraged states with bottle bills and mandatory recycling programs to include HDPE bottles in recovery programs, stressing stable and growing demand for this material.

*Eaglebrook Plastics* of Chicago operates a proprietary cleaning process for dairy and other post-consumer HDPE bottles, as well as a cleaning and regrind service for industrial scrap users. The firm operates twenty-four hours a day and processes one million pounds of material a month; it offers long-term contracts to recycling operators and in some cases offers granulators and shipping rebates. The company founder claims that demand for post-consumer HDPE is unlimited; he says the bottleneck is in persuading recycling programs to collect the material.

Eaglebrook Plastics recently opened a wholly owned subsidiary in Chicago that produces molded lumber and other profiles from recovered HDPE. Prices range from 8 to 17 cents per pound depending on whether milk jugs are mixed with other bottles and whether materials are baled or granulated. Eaglebrook will also broker other plastics as a service to recycling companies.

## PET: New Laws Spur 50 Percent Recycling Goal

In response to growing consumer and legislative pressure to recycle PET, major PET resin suppliers and bottle manufacturers in 1987 launched several aggressive initiatives to increase PET recycling and assure markets for reclaimed material. The umbrella group, the National Association for Plastic Container Recovery (NAPCOR), headquartered in Charlotte, North Carolina, has set a goal of achieving a 50 percent PET recycling level nationally by 1992. NAPCOR will focus initial efforts in seven states including California and New Jersey, where recent legislation mandates dramatic increases in PET recycling.

NAPCOR joined with local organizations to form the Plastic Recycling Corporation of New Jersey, which offers equipment funding, technical support, and marketing assistance to help persuade counties to include plastic beverage bottles in their recycling programs. The Plastic Recycling Corporation of California was similarly organized to guarantee PET markets and facilitate plastic bottle recovery under the new AB2020 law. The corporation has guaranteed recycling operators a PET price equal to the scrap value plus material handling costs.

These initiatives and promised R&D to create more product uses for post-consumer PET suggest that substantial increases in PET recovery and reuse will be seen in the next few years.

## Chicken and Egg: Encouraging Demand

Markets in the past year have illustrated a growing trend toward supply driven demand, that is, the creation of market capacity and thus demand by the presence of a strong and long-term flow of material. The already strong polyethylene market in the Midwest expanded from industrial scrap to post-consumer plastics when that material became available, while the PET market expansion is driven by legislation that guarantees a material flow. In some states, government procurement preferences promise to bolster the markets from the demand end while collection programs fuel the supply end.

Further product and market development are needed to bring the polyolefin pellet and mixed-plastic markets up to potential. Combined with the possibility of culling HDPE and PET at Massachusetts MRFs, such development would guarantee that the collection programs would have a broad-based and sustained market for their materials.

## REFERENCES

1. Chem Systems, Inc., *Plastics: AD 2000, Production and Use through the Turn of the Century,* Society of the Plastics Industry, Washington, D.C., 1987.

2. Resource Recycling, Inc., *Plastics Recycling Update,* February 1988.
3. M. Berins, *Plastics Focus,* The Plastics Connection, Inc., February 1, 1988.
4. J. Foote, Cap Cod Conservation District (Massachusetts), personal communication, February 1987.
5. M. W. Browne, World Threat of Plastic Trash Defies Technological Solution, newspaper and date unknown.
6. D. Dumanoski, A Plastic Sea, *Boston Globe,* October 22, 1987.
7. C. Flavin, *The Future of Synthetic Materials: The Petroleum Connection,* Worldwatch Institute, Washington, D.C., 1980.
8. Franklin Associates, Ltd., *Characterization of Municipal Solid Waste in the United States: 1960 to 2000,* U.S. EPA, 1986.
9. Massachusetts Division of Solid Waste Management, "Weight to Volume Measurements of Common Container Materials," internal document, May 1987.
10. *British Petroleum Statistical Review of World Energy,* London, June 1987.
11. J. Gever, et al., *Beyond Oil: The Threat to Food and Fuel in the Coming Decades,* Ballinger Publishing Company, Cambridge, Massachusetts, 1986.
12. M. G. Renner, Car Crash: Oil, Debt and the Future of the Automobile, *World Watch,* January-February 1988.
13. U.S. Department of Energy, *Energy Security: A Report to the President of the United States,* Washington, D.C., March 1987.
14. J. Wirka, *Plastics Packaging in the Environment: A Case Study for Source Reduction,* Environmental Action Foundation, Washington, D.C., April 1988.
15. Resource Integration Systems, Ltd., *Market Study for Recyclable Plastics: Background Report,* Michigan Department of Natural Resources, Lansing, 1987.
16. M. Schedler, Bronx 2000, personal communication re: lab tests of recovered plastics, January 26, 1988.
17. G. Pess, *Thermoplastics in the Postconsumer Waste Stream,* Environmental Action Coalition, Washington, D.C., 1985.
18. R. H. Boyle, Forecast for Disaster, *Sports Illustrated,* November 11, 1987.
19. N. Sherman, presentation to the Rhode Island Source Reduction Task Force on behalf of the Food Service and Packaging Institute, January 6, 1988.
20. B. Russell, presentation to Rhode Island Source Reduction Task Force on behalf of Amoco Foam Products Corporation, January 6, 1988.
21. *TechPak,* McGraw-Hill, February 1, 1988.
22. Quoted by B. Hinkley, Florida Department of Environmental Regulation, SPI Rigid Container Division meeting, March 10, 1988.
23. R. Lampi, Coalition for Recyclable Waste, personal communication, January 1988.
24. Midwest Research Center, *Results of the Combustion and Emissions Research Project at the Vicon Incinerator Facility in Pittsfield, MA,* New York State Energy Research and Development Authority, Albany, 1987.
25. A. Hirsch, U.S. EPA, written comments to FDA on environmental impacts of proposed increase in PVC food packaging, undated, received by FDA June 2, 1986.

26. Plastic Waste Management Institute, *Plastic Waste: Resource Recovery and Recycling in Japan,* and *Updated Data Addendum,* Tokyo, 1985 and 1986.
27. SCS Engineers, RAS Associates, and Recon Systems, *Study of Municipal Solid Waste Quality, Composition, and Full Characteristics in Essex, Hudson and Union Counties,* Port Authority of New York and New Jersey, New York, 1982.
28. *Source Separation, Feasibility Study for Wayne County Michigan,* Southeast Michigan Council of Governments, Michigan, 1981.
29. *Islip Solid Waste Management Plan,* Town of Islip, Long Island, New York, 1982.
30. *Northeast Michigan Waste Stream Assessment,* Northeast Michigan Council of Governments, 1980.
31. University of Arizona and University of Wisconsin, *The Milwaukee Garbage Project,* Solid Waste Council of the Paper Industry, 1981.
32. Tenech Environmental Engineers, *Kent/Ottawa Resource Recovery Project,* Ottawa, 1983.
33. Lavalin, *Etude sur les Dechets: Rapport de Mission,* Montreal, 1984.
34. Secondary Resource Development Consultants, *Waste Sources, Quantities, and Composition in Atlantic County,* 1984.
35. Klockner Industrie-Anlagen GmbH, *Recycling Zoeter-meer,* Duisburg, FRG, 1985.
36. Roche et Associates, *Impact de la Collecte Selective sur le Territoire de la CUQ,* Quebec City, Quebec, 1986.
37. International Plastics Consultants Corporation, personal communication, February 1988.
38. Center for Plastics Recycling Research at Rutgers, personal communication, January 1988.
39. J. Milgrom, Identifying the Nuisance Plastics, *New Scientist, 57,* 1973.
40. Centre de Recherche Industrielle du Quebec, *Composition des Plastiques Presents dans les Ordures Municipales de la CUQ,* Quebec City, August 1986.
41. ANRED, *Caracteristique du Marche des dechets de matieres plastique en France,* France, June 1983.
42. VanNostrand Remhold Co., *Energy in Packaging and Waste,* Workingham, U.K., 1983.
43. International Plastic Consultants Corporation, *Plastic Packaging Quantities Potentially Available 1987-2000,* January 1988.
44. R. Cunningham, Massachusetts Soft Drink Association, personal communication, January 1987.
45. S.S.I. Schaeffer, "Waste Collection with Separation of Domestic Refuse and Recyclable Waste," presentation at Pennsylvania Recycling Conference, May 1987.
46. M. Schedler, Bronx 2000/R2B2, personal communication, December 1987.
47. A. Aitchison, Naperville Area Recycling Center, personal communication, December 1987.
48. Resource Integration Systems, Ltd., *Statewide Market Study for Recycled Plastics,* Michigan Department of Natural Resources, February 1987.

49. "An API Overview of Degradable Plastics," presented at SPI symposium, June 10, 1987.
50. T. Andrady, Research Triangle Institute, North Carolina, presentation to Suffolk County Waste Management Task Force, State University of New York at Stony Brook, January 26, 1988.
51. M. S. Dukakis, Governor, Executive Order 279, May 18, 1987.
52. *TechPak,* McGraw-Hill, various issues, from November 1987 through March 1988.
53. M. Berins, *Plastics Focus,* The Plastics Connection, Inc., March 14, 1988.
54. G. M. Boyd, *Outlook for Plastics,* Chemical Data, Inc., March 1988.
55. S. Silver, Deer Polymers, personal communication, November 1987.
56. G. Jecha, Allied Signal, personal communication, March 1988.
57. New Plastics Market Developing, *Recycling Today,* December 1987.

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