MBA Polymers

Richmond, California

Use of Recovered Plastics in the Manufacture of Automobiles, Appliances & Electronic Equipment

(Recycling of Mixed Plastics)

Commercial Demonstration – Reported Fall 1999

MBA Polymers, Inc.

Final Report

Use of Recovered Plastics in the Manufacture of Automobiles, Appliances, and Electronic Equipment

National Industrial Competitiveness Through Energy, Environment, and Economics (NICE^3) Grant No. NIC-95-083

Abstract

In August 1995 MBA Polymers, Inc. was awarded a NICE3 grant to pursue commercialization of a new variety of durable goods plastic recycling technology. During the grant period (8/95 – 3/99) MBA Polymers built a processing facility to overcome many of the challenges of recovering plastic from the manufacture of automobiles, appliances, and electrical and electronic equipment. This plastic scrap in the past was often placed in landfills. MBA has demonstrated on a commercial scale key advanced size reduction, materials liberation, materials separation, and cleaning technologies to recover this plastic.

MBA's processing plant is capable of running at rates of up to 5000 lb / hr[1] and purifying as many as three plastics, though, for economic reasons most frequently only one plastic is targeted. The process consumes about 0.2 kWh / Kg of plastic flake produced or approximately 330 Btu / lb[2]. If this product were pelletized the total energy consumption would rise to approximately 0.6 kWh / Kg or 930 Btu / lb. This energy utilization represents 97% energy savings when compared to the 40,000 Btu / lb virgin-resin manufacture is estimated to require[3]. MBA successfully reduced energy use to substantially below the 2500 Btu / lb projected for the recycling process in the original grant proposal[4] by improving efficiency.

MBA continues to process a variety of streams from various commercial sources. By mid-1998 MBA had processed more than 2 million pounds of material using the process implemented under this proposal. MBA projects to process in excess of 7 million pounds in 1999. MBA's revenues have grown to more than $2.3 million in 1998 and MBA now employs more than 30 people. The process is economically viable for a large number of post-manufacturing streams now and more are being demonstrated monthly. The largest disadvantage of the process is that it cannot recover materials effectively from a truly mixed stream, which limits its scale. This capability would be required to handle post-consumer goods.

The economics of durable goods recycling are promising and MBA hopes to dramatically expand its operation in the near future. MBA is establishing commercial sourcing partnerships with a large waste handler and supply contracts with automotive and

computer manufacturers. To finance its expansion, MBA is seeking funding from venture capital firms and bank loans. MBA has presented its business plan at three investor forums including the Environmental Capital Network, for which each presenter must pass a screening process showing strength in management, marketing and technology.

Introduction

A considerable amount of scrap is generated in the production of plastic durable goods. For simple plastic products, typically packaging materials and other single material goods, scrap recovery is straightforward. However, for more complicated products, particularly multi-component durable goods, the plastic scrap is often contaminated with paint, fillers, metals, foams, and other materials (including mixed plastic types) which make recovery by the manufacturer difficult. In selected cases, a small quantity of durable goods can be sorted manually to purify plastics, but in general in the U.S., manual sorting is not cost-effective. Therefore for energy and waste purposes, MBA chose to compare to virgin plastics production against which recycled materials must always compete economically.

A wide variety of post-consumer plastics can be used for recovery.

MBA receives material from a growing number of producers of durable goods who are taking responsibility for the return of obsolete products. This is particularly dramatic in the computer industry where products are replaced well before the end of their useful life because of faster new technology. As with manufacturing scrap, this returned plastic is contaminated with a variety of other materials. Whereas useable components and precious metals are recovered, the plastic housing, by far the largest volume material, is discarded for lack of cost effective recycling technology. In fact, only about 2% of the plastic from computers is recovered today, largely because of technical, economic and infrastructure barriers. This represents a tremendous growth opportunity for the plastic recycling industry.

MBA Polymers targeted the approximately 4,000 million pounds of plastic used to produce automobiles, appliances, and electronic equipment. We estimate the overall scrap rate to be 10%, which amounts to approximately 400 million pounds annually of wasted plastic in the U.S. Not only does this material consume valuable landfill space, but the energy content of the plastic is approximately 8 trillion Btu. Reusing the plastic via effective processing is the best alternative to wasting this valuable resource.

The industries we are targeting use a variety of plastic types including Polysulfone, ABS (acrylonitrile-butadiene-styrene), HIPS (high impact polystyrene), polypropylene, polyurethane, polyvinyl chloride, polyethylene, polyester, nylon, and polycarbonate. To accomplish the objective of using recovered plastics to produce durable goods, an advanced mechanical recovery technology has been developed by MBA Polymers with partial funding from NICE3, the American Plastics Council (APC) and plastic end-users. The various stages in this process have been integrated in a single line by MBAP.

Objectives

Although some scrap plastic streams generated at durable goods manufacturing or recovery sites are relatively clean and are readily reclaimed today, virtually all of the dismantled automotive parts, computers, business equipment, appliances, etc. are made of mixed materials which must be liberated and separated from one another. These streams involve challenges that prohibit recovery. Conventional plastics cleaning and sorting processes (e.g. as used for bottle recycling) are completely inadequate to handle these streams. Examples of some of these challenges include:

- Mixtures of different *types* of plastics, some with various types of *fillers* and *additives*.
- Items constructed of *multiple* plastics.
- Paint and metallic *coatings*.
- Significant amounts of attached *metal.*
- Other non-plastic items such as *natural rubber, elastomers and glass*.
- Parts containing attached *foam*, *fabric* or plastic *films* made of different materials.
- Large and *variable thickness* wall sections which make size reduction and control challenging.

The technical goal of this project was the commercial demonstration of several key advanced size reduction, materials liberation, materials separation, and cleaning technologies for plastics which combine to produce an advanced plastics recycling system that will offer many capabilities not available today, including:

- Enhanced size reduction throughput, equipment wear, energy consumption and particle size and shape control.
- Reduced product and side-stream contamination.
- Enhanced process control of heavy media systems for multi-material separations.
- Advanced material separation capabilities.
- Closed, high throughput, efficiency and simplicity.

The unit operations discussed below were selected and developed to realize a technical breakthrough and/or a significant performance and economic enhancement over the few approaches in existence. The NICE[3] award was used to fund the air classification, grinding and density separation systems. This included the purchase of both new and used equipment, engineering and installation. A diagram of the process line is given in Figure 1.

The size reduction system is unique in several important respects compared to traditional size reduction equipment used for plastics: it can tolerate high amounts of metal contamination, it can produce uniformly sized and shaped particles which are very important to effective separation operations, it has low maintenance requirements and it has extremely high throughput/energy consumption ratios. These benefits are realized by using a highly modified rotary grinder, traditionally used in the wood processing industries to do coarse, high throughput size reduction, followed by magnetic metal removal in preparation for further grinding.

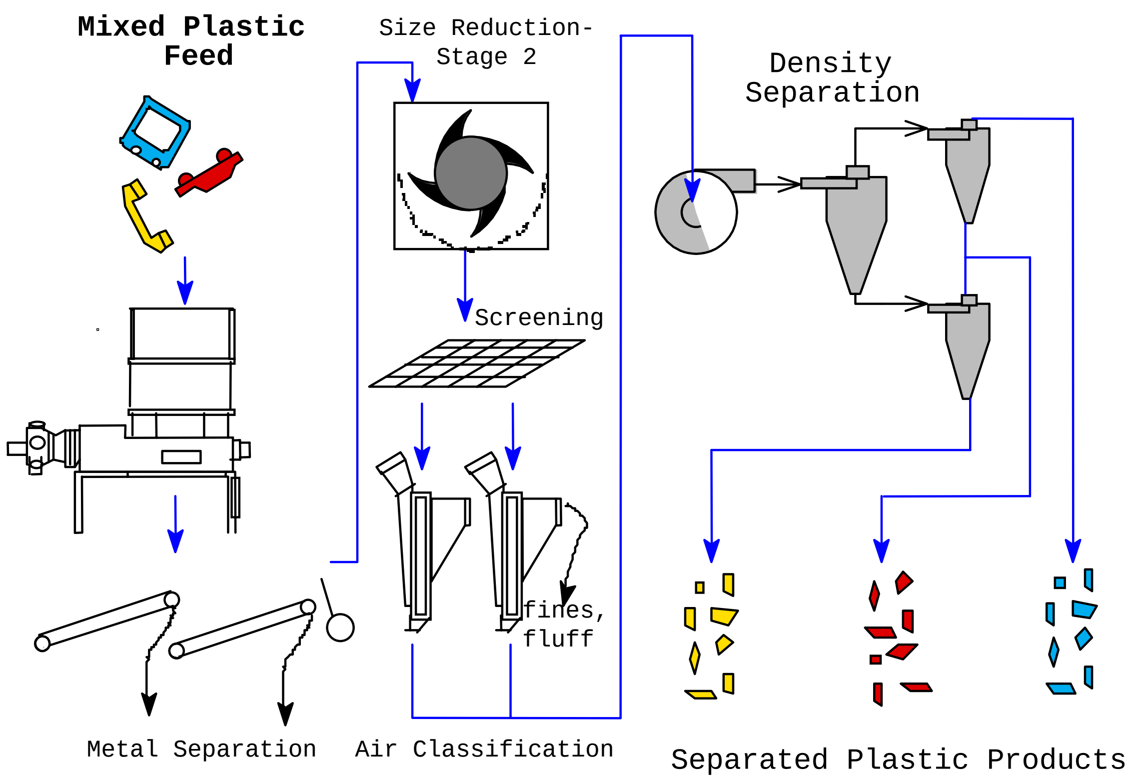

Figure 1. MBA Polymers State-of-the-Art Plastics Recycling Process.

The Hydrocyclone begins the separation process.

The separation systems used to separate various plastic fractions are innovative for their simplicity of design, low capital costs, low operating costs, operating flexibility, robustness, and precision of separation capabilities. Several of the heavy media hydrocyclone separators use sophisticated control systems that will enable them to quickly change operation parameters to accommodate material changes and provide excellent process control capabilities. Again, the media and operating parameters used were designed by MBAP for difficult plastics separations. The process is automated and continuous. The combination of these unit operations into a single process line is necessary to realize the economic and product quality benefits.

Examples of Material Flow and Yield

MBA Polymers recovers materials under a number of different business models including toll processing and purchase of scrap for sale. The system can be used to recover a broad range of plastics including ABS, PP, PSU, PC/ABS, PC, HIPS, PPO, PA, and PBT among others. Examples are given below of three types of recycling operations on three different types of plastics, which MBA has undertaken. The recovery of Polysulfone, a very valuable plastic, has been a significant commercial undertaking for MBA Polymers.

As a case study, material flows and yields are given in Figure 2 to demonstrate the successful recovery of this specific feedstock using the process. Nearly 1 million pounds of this material alone have been recovered.

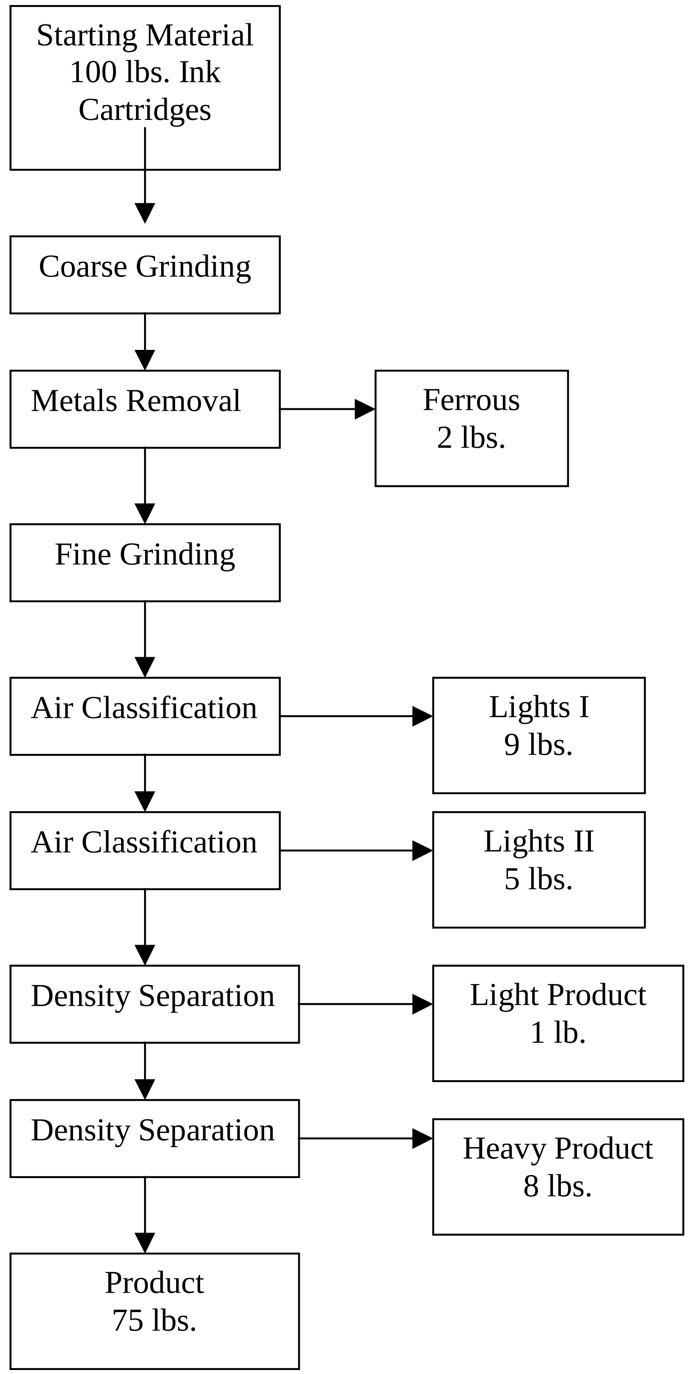

Figure 2. Material Flow Diagram for Polysulfone Recovery

The separation process produces many different plastic products at a time.

MBA's process can also be used when the primary goal is metals recovery. Anti-lock brake housings are a complex parts to manufacture. Since all parts must be working perfectly before the housings can be installed in automobiles, a high scrap rate results. These housings contain precious metals, copper, aluminum, and steel as well as valuable Polybutylene Terephthalate, PBT. In this instance the primary economic driver for recycling is the recovery of the metals. MBA's process does this challenging job very well. MBA is paid on a tolling basis and returns all materials to the part manufacturer. Figure 3 illustrates the process and material yields. In this instance only the first stages of MBA's line are necessary.

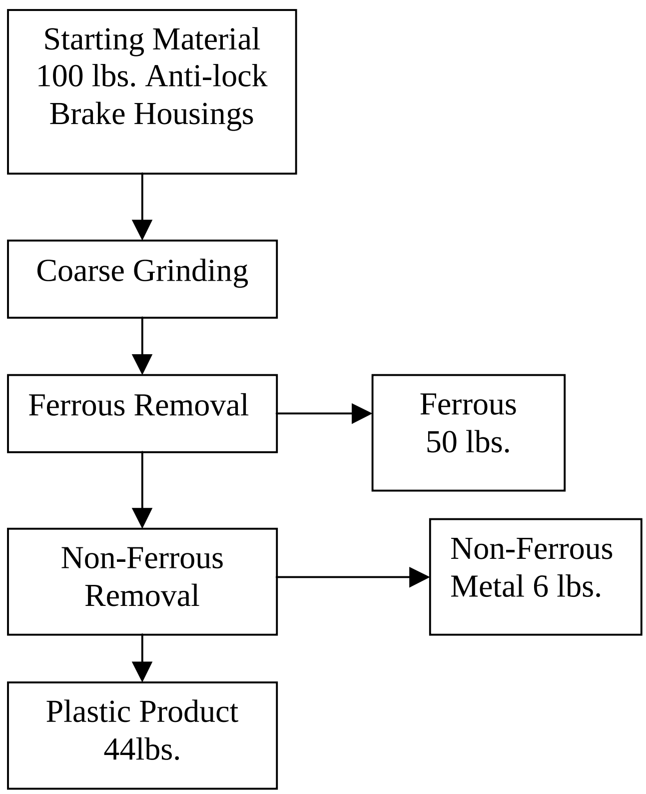

Figure 3. Material Flow Diagram for Brake Housings Recovery

The major purpose of MBA Polymers' line is production of plastic for sale. An example of this method of operation is the purification of ABS from computer housings. MBA has just begun this mode of operation because it is the most difficult from a quality control standpoint. MBA has produced close to 1 million pounds of this material and will focus most future production on products like ABS, HIPS, PC/ABS and PC. The material flow diagram for ABS recovery is given in Figure 4.

Both the product and ferrous metal are recovered in this scheme for a total of 70% recycled yield. The lights, fines and heavies products could be recovered in the future when applications for them are developed.

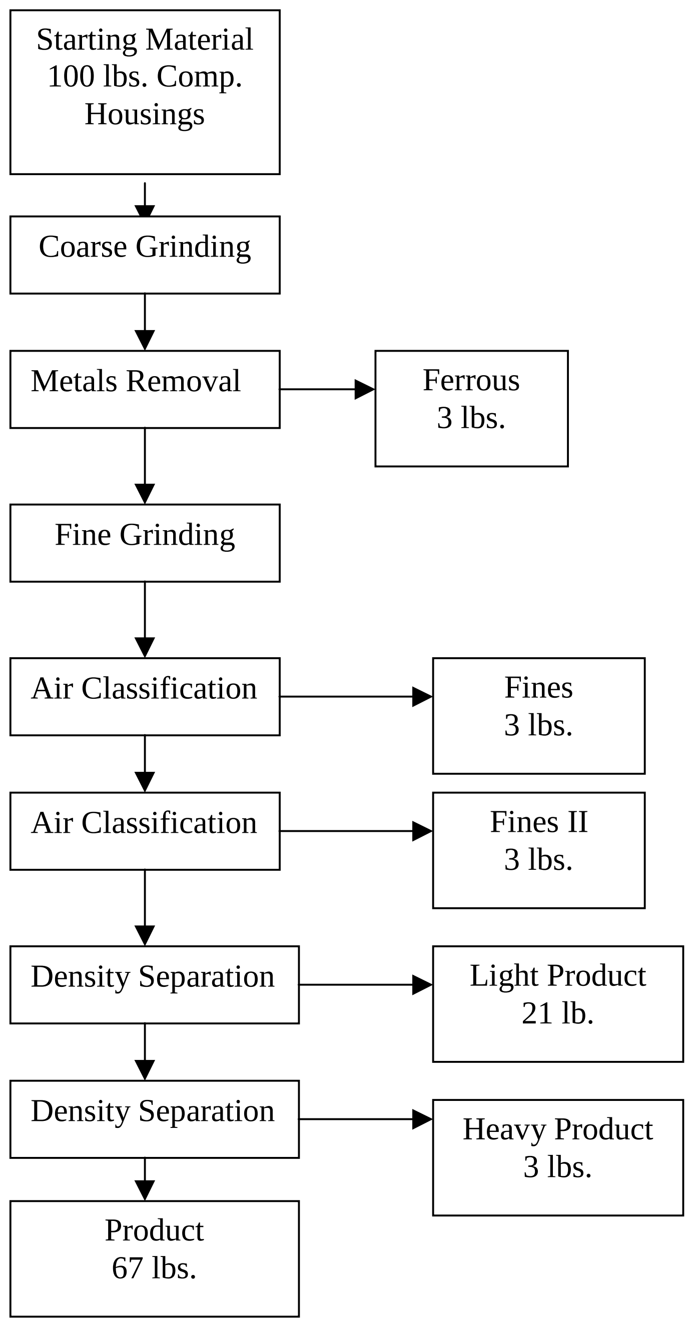

Figure 4. Material Flow Diagram for ABS Recovery

The primary limitation of the processing system is that it only produces one density product which is bracketed on both the high and low sides. The high density and the low density products are not bracketed. This means that impurities can be removed from the product which reports in the middle density range, but then these impurities are sent to either the high or low density ranges. This limits the systems capability to purify the materials which report to the high and low ranges. MBA is planning to improve the system by adding additional density sorting stages. The more density sorting stages which are added the more purified (bracketed) products can be recovered from a given feed. Density-based purification does not work when materials overlap in density. The current MBA system requires that feed materials be quite controlled to ensure that they do not contain polymers that overlap in density as would be found in a complex post-consumer stream. MBA's current system is most effectively applied to post-industrial scrap for this reason.

The extrusion process performs the final purification of the product.

Extensive analysis is necessary to ensure that the final product is pure enough to compete with plastics made from fossil fuels.

The final product of the plastics recycling process is a high quality pellet ready for any number of uses.

MBA's Recycling Economics
MBA typically buys or is paid to take material, depending on the difficulty involved in processing it to produce pure plastic and the value of the resulting plastic. Acquisition costs vary between (-$0.30) - $0.10 / lb. but are typically about $0.06 / lb. Processing costs also vary dramatically from as low as $0.05 /lb. to as high as $0.45 / lb. but are typically $0.15 / lb. The sales price for plastics vary with the virgin price. MBA typically targets about 75% of the virgin sales price as the recycle value. Figure 5 shows how virgin prices have varied for the past few years for some of the materials which MBA recycles.

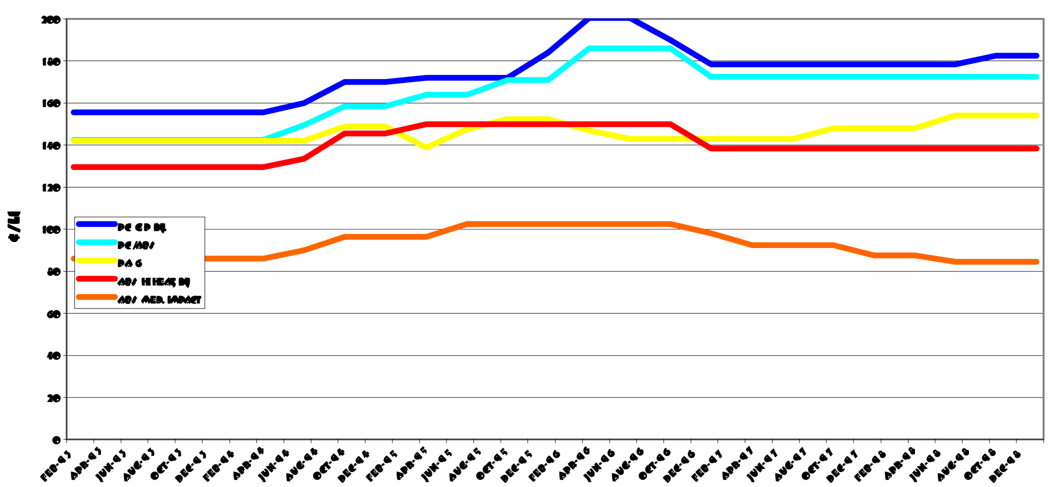

Figure 5. Virgin Plastic Prices

The durable plastic recycling business can be much more profitable than the HDPE or PET recycling business. It can also be a less cyclic business. MBA has estimated what it's gross margins would have been based on resin specific raw material and processing costs. These margins are given in Figure 6 below. An estimate of the gross margin for PET and HDPE recycling is also given. It can be seen from the figure why many plastic packaging recyclers have gone out of business.

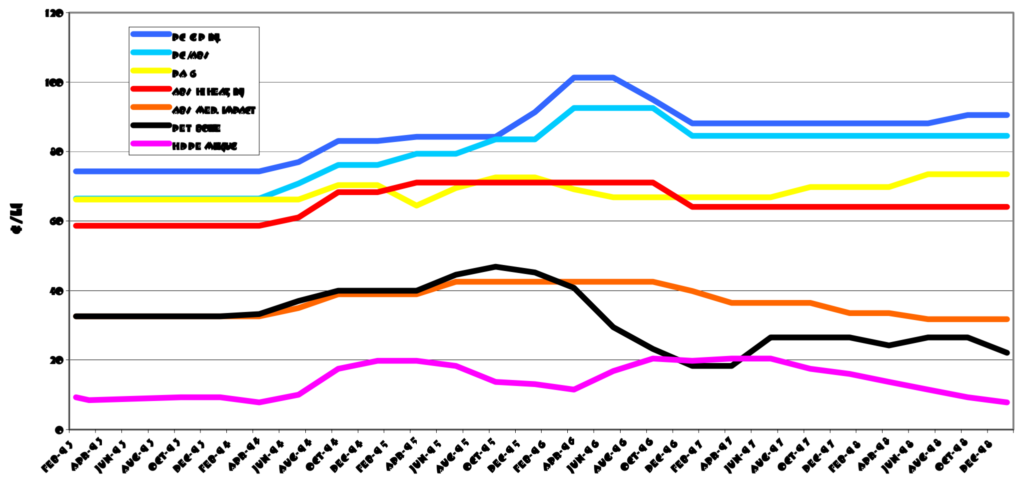

Figure 6. Estimated Gross Margins for Plastics Recycling

Commercial Activities

MBA Polymers has grown since 1995 from total revenue of less than $0.7 million to more than $2.3 million in 1998 and has in excess of 30 employees now. Much of this growth has been due to the strong reception from the market for the sorting of durable plastics, which are in high demand. MBA now runs two processing lines that grind and purify plastic feeds. MBA has several different varieties of commercial contracts. We toll process for customers like Hewlett-Packard, who seek to reuse plastic themselves or separately market it. We purchase materials from recyclers and waste haulers like Waste Management who service corporate clients and obtain sources of manufacturing scrap. We also purchase materials directly from manufacturers for resale. By mid-1998, we had processed well in excess of 2 million pounds of material.

Plan for Commercial Expansion

MBA is actively seeking to expand the scope of materials that can be recovered. In the summer of 1998, MBA made a decision to pursue a mixed waste stream as its primary feedstock. This will enable MBA to capture not just the 10% of plastic represented by manufacturing scrap but also the other 90% that reaches consumers. This pivotal decision would expand potential raw material available by ten times and dramatically reduce the cost of raw material for MBA's plants in the long-term. The reduction in raw material cost stems from the removal of expensive infrastructure requirements to sort, store and separately ship enriched (i.e. 60% one plastic variety) material. We feel this project has huge commercialization potential.

MBA is in discussions with several major international waste firms including Waste Management (now a subsidiary of USA Waste), BFI and Allied to secure sourcing contracts for raw material. MBA provides the missing link for these organizations by providing a large volume, credible recovery alternative for durable plastics. Durable plastics are one of the only materials not adequately addressed under current handling scenarios. MBA hopes that these discussions will lead to a sustainable sourcing infrastructure with benefits for all parties involved.

MBA is seeking to transfer the technology package on the coarse size reduction and metals removal to waste haulers, recycling companies and communities who want to install their own systems to start-up process plants to sell mixed plastics. It will not be cost-effective to sort plastic in these small local plants. We anticipate that the technical transfer of this system will be made by a combination of licensing, free transfer and captive installations. Further activities in commercialization for sourcing will be borne by individual recycling companies and community waste collection sources who will be motivated to produce revenue from plastics which are now a costly waste. These groups will earn additional revenue from sale of metals that cannot be cost-effectively recovered individually today.

MBA has also partnered with several large original equipment manufacturers to provide low cost plastic feed streams for production. One of the most promising areas for these partnerships is the automotive industry. General Motors alone purchases more than $1 billion worth of plastic each year. MBA is seeking to expand its contract with automobile manufacturers to include long-term supplier agreements on specific plastic types. All three major US auto manufacturers have targeted use of recycled plastics as a way to cut production costs. GM hopes to reduce per-vehicle costs by as much as $25 in this way. Chrysler (now Daimler-Chrysler) has stated the goal of incorporating 30% recycled plastic content in vehicles by early 2002. Ford has launched a nationwide ad campaign promoting its continued use of recycled plastics.

MBA Polymers with the technology developed under the NICE3 grant has emerged as the only credible link to enable the large scale recovery of materials from sources like Waste Management to provide near-virgin quality for customers like General Motors. Growing at this rate will prove a challenge and MBA is seeking to raise financing from private venture capital firms. MBA has received independent validation from investors for its technology and marketing approach by being allowed to present at both the East and West Coast Environmental Capital Network Forums. All presenters to these forums are reviewed and selected based on criteria such as management quality, technological approach and market size.

Basis for Energy Comparisons
The current technology for comparison is a virgin ABS production plant with a capacity of approximately 500 million pounds per year. Virgin plastic production consumes 20,000 Btu/lb. and the equivalent of 20,000 Btu/lb. are feedstock for that production. Plastics are made from a combination of monomers, sometimes with the addition of modifiers such as rubber. Hydrocarbons are processed to produce the monomers, which are combined under temperature and pressure to form the polymer product[5]. For example, ABS is produced from a copolymer of styrene and acrylonitrile with styrene-butadiene rubber added to increase impact resistance. This typical process is the basis for our energy and cost efficiency calculations.

Considering energy requirements (feedstock and processing), sixty percent of the energy used is natural gas (most of it as feedstock), 22% is petroleum and the remaining 18% is coal, hydropower, and nuclear used to generate power.[6] In 1988, 4% of the total U.S. consumption of natural gas and petroleum was in plastic production, or 2,062 trillion Btu.[7] Half of this energy is contained in the plastic itself and is lost if the scrap is not recovered or is incinerated. Approximately 1000 Btu/lb are required for our process (rounding up from 930 Btus because feedstocks vary). No "raw material" energy is used. Using this recovered plastic instead of additional virgin plastic results in energy savings of 39,000 Btu/lb or more than 97% of the energy required for virgin plastic production.[8]

Waste Savings
Not only does MBA reduce waste directly by every pound of plastic recovered, a complementary reduction of the residual metal[9] is also realized. Note that this figure represents only the potential weight diverted. Volume reductions are more important in landfills. Each reduction of 1% by weight of plastics in a landfill translates to a reduction of approximately 2.5% by volume.[10] Using water to remove paint, metals, and other contaminants, we create a small solid waste stream. Our results indicate that this stream, which occasionally must be treated as hazardous, amounts to less than 0.05 percentage by weight.

Economic Competitiveness
Hand sorting of durable goods is not cost-competitive in the U.S. for reasons including high labor rates, inability to produce large volumes demanded by customers, and high cost of storing sorted products. Therefore, the comparison of interest is between the cost of virgin plastic and the cost of recovering plastic using our process. The weighted average of the prices of the plastics used in the industries we are targeting is $0.75/lb[11], our estimated average manufacturing cost is $0.50/lb, after accounting for profit and return on capital. This yields cost savings per pound of $0.25 to manufacturers or $750 million dollars annually by 2010.
Independent estimates of the cost for processing used engineering thermoplastics from sorted manufacturing scrap range from $0.25 to $0.35/lb, again depending on volume and the relative purities of feed and product.[12]

Marketing
Price, consistency, and eco-friendliness are our major marketing advantages. The one major deficit of recycled plastics with respect to virgin plastics is the loss of complete control over final color. Recycled plastics contain pigments and dyes that cannot be removed. For this reason and other reasons, we believe only about 25% of the durables plastics market can ultimately accept recycled plastics and a discount with respect to virgin is required to ensure sales. We have relied on communications with our customers to arrive at the required level of the discount. Our sales effort will maximize use of the Internet, which is proving to be an effective method of competing for sales with much better funded virgin plastic producers.

Conclusions
MBA's processing plant is capable of running at rates of up to 5000 lb / hr and purifying as many as three plastics in some cases, though most frequently only one plastic is targeted for economic reasons[13]. The process competes very effectively with virgin plastic production. The process requires plastic-rich feedstocks that are at least 60% one plastic variety for economic operation. This requirement for an enriched feed stream limits the scope of application of the process to post-manufacturing waste which represents only about 10% of the total durable goods plastic consumption.

The process consumes about 0.2 kWh / Kg of plastic flake produced or approximately 330 Btu / lb. If this product were pelletized the total energy consumption would rise to approximately 0.6 kWh / Kg or 930 Btu / lb. Pelletization is frequently required to realize strong markets for recovered plastic materials. We have found that flake materials may be unfairly blamed for processing inconsistencies and have decided to market pelletized products to avoid this problem when possible.

The MBA Process energy consumption represents 97% energy saving when compared to the 40,000 Btu / lb virgin resin manufacture is estimated to require. MBA successfully reduced energy use to substantially below the 2500 Btu / lb projected for the recycling process in the original proposal by improving efficiency.

To satisfy a growing demand for recycled plastics MBA has decided to de-bottleneck its sourcing by commercializing a process to sort entirely mixed sources. This will enable the processing of post-consumer materials as well as post-industrial and will increase available raw material by a factor of ten while reducing costs.

The economics of durable goods recycling are very promising. MBA hopes to dramatically expand its operation in the near future and is seeking substantial funding from venture capital firms and others to do so.

Table of Abbreviations (Acronyms)

ABS	acrylonitrile-butadiene-styrene
APC	American Plastics Council
HDPE	high density polyethylene
HIPS	high impact polystyrene
NICE[3]	National Industrial Competitiveness through Energy, Environment, and Economics
PA	polyamide
PBT	polybutylene terephthalate
PC	polycarbonate
PET	polyethylene terephthalate
PP	polypropylene
PPO	polyphenylene oxide
PU	polyurethane
PVC	polyvinyl chloride
PSF	polysulfone

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[1] Production rates depend on the type of material being processed and the purity required for sale.
[2] Energy consumption all in form of electricity and based on average total production loads over a one month period.
[3] Use of Recovered Plastics in the Manufacture of Automobiles, Appliances and Electronic Equipment, MBA Polymers NICE3 Proposal, January 1995, p. 11.
[4] Ibid. , p. 6.
[5] Shreve's Chemical Process Industries, 5th ed., Mc Graw Hill, 1984, p. 661
[6] Facts and Figures of the U.S. Plastics Industry, The Society of the Plastics Industry, Inc. 1993.
[7] Plastics and the Environment, The Society of The Plastics Industry, Inc. , 1991, P. 47.
[8] Note: 11,200 Btu/lb of natural gas and 8,800 Btu/lb of oil used in the current process is excluded from waste calculation because it is the raw material used to make the plastic, and is not combusted. For these calculations, we used, on a per pound of product basis: 12,800 Btu (gas), 5,200 Btu (coal) and 1,000 Btu (elec.) for a virgin plant; and 1,500 Btu gas and 1,000 Btu electricity for the recycling plant.
[9] Plastic-rich can sometimes be a misnomer. Some of the streams may be 50% metal by weight. By recycling plastics, many additional metals are also recovered that would be landfilled because they are attached to plastics. Household End-of-life Electrical and Electronic Equipment: Pilot Collection Report EPA-901-R-98-002, February, 1998
[10] Garbage, Trash, Refuse, Waste, Discards, Rubbish, & Junk, The Book 2, Nichols and Dezenhall Communications Management Group, 1992, p. 40.
[11] Compiled from **Plastics News**, July 1998.
[12] Plastics Reclamation and Recycling, SRI International, January, 1992, p. 8-4.
[13] Throughputs and number of products vary with feed.