

# **The Evolution of Plastics Recycling Technology**



American  
Plastics  
Council

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# The Evolution of Plastics Recycling Technology

## Overview

The U.S. Environmental Protection Agency (EPA) defines recycling as “the process by which materials otherwise destined for disposal are collected, reprocessed or re-manufactured, and reused.”<sup>1</sup>

In his book *Earth in the Balance*, Vice President Al Gore refers to recycling as “the reintroduction of what used to be considered useless waste back into the stream of commerce.”<sup>2</sup>

The State of Oregon defines recycling as “any process by which solid waste materials are transformed into new products in such a manner that the original products may lose their identity.”<sup>3</sup>

Regardless of who's doing the defining, for Americans, the term recycling means:

- conserving natural resources;
- reducing waste; and
- producing useful products from material that may otherwise become trash.

In fact, public opinion research conducted by Cambridge Reports Research International found that 84 percent of adult Americans defined recycling as a product or package “used again for another purpose.”<sup>4</sup>

Many of today's environmentally conscious consumers consider recycling a relatively recent enterprise born of the environmental

movement that swept this country in the early-1970s. Nothing could be further from fact.

In the Americas, evidence of archaic forms of recycling has been found in Mayan ruins dating back a millennium.<sup>5</sup> Moreover, a wealth of information is available documenting extensive recycling programs undertaken in major American cities prior to the turn of the century. These programs tended to focus on waste reduction and sanitation as their primary objectives.

For example, in January, 1898, the City of New York established the first rubbish-sorting facility in the United States for the express purpose of facilitating resource recovery and recycling.<sup>6</sup> George E. Waring, Jr., the city's progressive street-cleaning commissioner, recognized the value of saving natural resources and converting waste into useful products. In an article entitled, “The Disposal of a City's Waste,” Waring observed:

*Dickens' "Golden Dustman" and the accounts of the rag-pickers of Paris have made us familiar with the fact that there is an available value in the ordinary rejectamenta of human life. We learn by the work of the dock Italian of New York that to regain this value is a matter of minute detail; it calls for the recovery of unconsidered trifles from a mass of valueless wastes, and the conversion of these into a salable commodity.*<sup>7</sup>

The volume of materials recycled in the United States increased markedly during World Wars I and II. The motivating factor for wartime recycling had little to do with concerns about the environmental effects of waste disposal facilities and littering. Americans viewed recycling as their patriotic duty — conserving natural resources (steel, tin, rubber, aluminum, paper, petroleum and other materials) that were desperately needed by U.S. military forces overseas.<sup>8</sup>

Thus, today's recycling ethic, which emphasizes resource conservation, waste avoidance, and materials recovery and reuse,

is not a revolutionary concept brought to life on the first Earth Day. Instead, it has literally evolved over the centuries. And, just as the recycling ethic has evolved, so has the technology used to recycle materials that would otherwise find their way to a waste disposal facility.

This paper examines the evolution of recycling technology and highlights advanced technologies that enhance the effectiveness and efficiency of the recycling systems operating today, and those that will process recyclables in the future.

## The Evolution of Recycling Technology

Throughout history, recycling technology has moved through four evolutionary stages:

- Stage I** Reuse
- Stage II** Reshape
- Stage III** Remold
- Stage IV** Reprocess

Excavations of Mayan temples have produced evidence that the Mayans recycled broken pottery and worn-out living utensils into construction material — extracting additional value from items that would otherwise have been discarded, and saving the human energy and natural resources required to extract “virgin” construction material from the earth.<sup>9</sup>

While this archaic form of recycling did not maintain or upgrade the “value” of the material being recycled, it did conserve and reuse natural resources, reduce waste and produce a product (construction material) that had utility in the marketplace.

Archaeologists and historians have also found evidence of other rudimentary recycling technologies dating back several thousand years. Clay pottery, clothing, scrolls, and glass and metal objects were recycled into new and useful products using early recycling technologies that involved the reshaping of a discarded item into a new product, often with equal value, whose physical characteristics were similar to the item being recycled. In this

manner, a broken clay pot became a small bowl or eating utensil. A worn-out sword might have become a plow-like device.

With increased knowledge came innovation and the third evolutionary stage of recycling technology. This is the stage at which recyclers began applying heat to metal and glass objects that had served their useful purpose, allowing for a more precise, less time-consuming manipulation of the item being recycled into a form that had equal value. This remolding technology had its limitations, but was clearly more efficient and effective than the earlier reshaping technology.

The fourth and most advanced stage of recycling technology, used throughout the industrialized world today, involves reprocessing a recyclable item back to the basic material from which it was made and then re-manufacturing the material into useful, marketable products.

These advanced forms of recycling often utilize thermal or chemical methods to reprocess used products back to raw material. Like other forms of recycling, advanced recycling technologies meet the three criteria necessary for “true” recycling by:

- conserving natural resources;
- reducing waste; and
- producing new and useful products.

## **Advanced Recycling Technologies: Applications**

What follows are brief descriptions of how advanced recycling technologies are applied to the products and packages that are placed in recycling bins in thousands of communities across America today.

### **1. Steel<sup>10</sup>**

Cars, large appliances, machinery, construction beams and steel cans of all shapes and sizes provide the steel scrap that for decades has been essential in the recipe for new steel. Steel mills, foundries and detinning companies serve as markets for recycled steel products.

The advanced recycling technology used to recycle post-consumer steel products and containers uses heat to reprocess recyclables back into raw steel. Steel melts at roughly 2700° (F). Steel mills that utilize the basic oxygen furnace can accept 20 percent to 30 percent scrap steel mixed with the virgin materials used in the steel making process. Mini mills, which use the electric arc furnace, process virtually 100 percent steel scrap to make new steel for the marketplace.

At the high temperatures used to melt post-consumer products back into raw steel, contaminants that may accompany the steel recyclables into the furnace (food waste, product residues, labels, etc.) are frequently destroyed by combustion. Any emissions that may result from the steel recycling process are managed by pollution abatement equipment and regulated by the EPA and local government agencies.

When a used steel can (or auto body) is melted back into raw steel, it becomes available for use in a wide array of steel products manufactured for commerce. While it is technically impossible to determine where every recycled steel can will end up after being melted, the fact remains that the material value of each recycled can contributes to the production of a new and useful product. In the process, natural resources are conserved and valuable material is diverted from the waste stream.

Detinning companies also play an important role in recycling steel cans. Through a chemical and electrolytic process, detinners remove the tin plate from used steel cans. Many of the detinned cans are then recycled back into raw steel at mills and foundries. The tin is sold in commercial markets.

It is worth noting that detinned steel cans are also used as "precipitation iron" for the recovery of copper from low grade ores. The cans are placed in a solution of copper sulfate that causes a chemical reaction which, in turn, precipitates the copper from the solution for extraction. This process ensures that copper that is difficult to recover in ore that has already been mined, can be used. Thus, steel cans facilitate the efficient use of natural resources and help reduce the need for increased mining activity. Many of the steel cans collected in California for recycling are used for copper precipitation. California recognizes this process as a legitimate form of recycling.

## 2. Aluminum<sup>11</sup>

Aluminum recycling dates back to the mid-1800s. However, consumer involvement in aluminum recycling began only after the introduction of the aluminum beverage can in the 1960s.

Ironically, when the aluminum beverage can was first introduced environmental groups actively sought to force its removal from the marketplace with "ban-the-can" legislative proposals. Today, environmentalists use the aluminum can as a recycling standard against which other packages are evaluated.

The advanced recycling technology used to recycle aluminum is quite similar to the technology used for steel. Post-consumer aluminum products are collected, densified (shredding, baling or compacting) and then cleaned. Following the cleaning process, the recyclable aluminum may be run through a de-lacquering system that burns off coatings and other residues that are present on the material. The used aluminum is then reprocessed in a furnace at about 1100° (F), and recast into new aluminum ingot for use in the manufacture of a variety of new products.

As with other materials such as glass, paper, plastics and steel, there are many forms of aluminum. Products often contain different aluminum alloys that influence the performance characteristics of the product. For example, lead helps the machining characteristics of aluminum, while copper contributes to its strength. With the exception of magnesium, the metals which form the different alloys of aluminum cannot be removed during recycling. Thus, the alloy of scrap aluminum must be considered during the recycling process to ensure that the

recycled aluminum meets end-product performance requirements.

Aluminum recycling conserves natural resources, diverts material from the waste stream and results in the production of new and useful products. It also saves a significant amount of energy. According to John Young, a research associate at the Worldwatch Institute, "it takes the (energy) equivalent of a quarter can (3 ounces) of gasoline to make one aluminum beer or soda can from bauxite, the metal's principal ore."<sup>12</sup> The can manufacturing industry reports that recycling aluminum cans saves 95 percent of the energy required to make aluminum from ore.<sup>13</sup>

## 3. Glass

Glass was first used in Egypt and Babylon for jewelry and small containers. During the first century A.D. Syrian artisans discovered that molten glass could be blown into different sizes, shapes and thicknesses, which eventually led to the mass production and wide availability of all types of glass products. The first glass recycling probably occurred soon after.

Glass recycling is a fairly simple process. Used glass is collected, color sorted and crushed into small pieces called cullet. Color sorting is necessary because glass produced from cullet must meet strict buyer specifications. The cullet is then cleaned and screened for contaminants such as metals. Once the sorting, crushing and cleaning process is completed, the cullet is mixed with sand, soda ash and limestone, and then reprocessed in a furnace at temperatures up to 2800° (F). The new melted glass is then dropped into a forming machine where it is

blown or pressed into new products. Glass recycling conserves natural resources and diverts a significant amount of post-consumer glass from the waste stream.

Not unlike the basic oxygen furnace used in the steel making process, limitations exist on the amount of cullet that can be used as furnace feed. It is desirable to have at least 8 percent to 10 percent cullet in a furnace charge, with 25 percent cullet the most common mix.<sup>14</sup> Contaminants that may be mixed in with the cullet are burned off in the glass furnace.

#### **4. Paper<sup>15</sup>**

Paper recycling in the United States dates back to the turn of the century when America was the world's largest paper and paper products producer. At the time, American consumers led the way in the consumption of paper products.

As consumption increased, there was growing concern about deforestation. The paper industry responded by increasing the procurement of materials that could be turned into paper quickly and economically. In 1913 the industry imported 123,000 tons of rags and 380,000 tons of wastepaper for paper production. When overseas sources dried up during World War I, the paper manufacturers turned to major American cities for their source of recyclable wastepaper. By 1916, the United States produced in excess of 15,000 tons of paper each day, using 5,000 tons of used paper in the process.<sup>16</sup>

Modern paper recycling, like the advanced recycling technologies used for other materials, converts post-consumer paper products back into the pulp feedstock from

which they were made, allowing for the production of new and oftentimes different paper products. To ensure the quality of recycled paper products, post-consumer paper is sorted by type and grade before it is recycled.

Today, used paper is prepared or repulped by mixing it with water and beating it with a hydropulper, a device that separates the fibers from foreign materials and produces a pulp slurry. Foreign materials are filtered out of the slurry, which is then sent to a series of floatation units where it is aerated to allow ink to migrate to the surface as foam. This de-inking process is aided by the use of heat and chemical dispersants, detergents, solvents or defoamers.

The de-inked pulp, which is about 4 percent fiber and 96 percent water, is then formed into paper sheets, although some fiber refining or blending may be necessary. In some cases, the pulp must be bleached with chlorine gas, sodium hypochlorite, hydrogen peroxide, oxygen or other chemicals prior to paper making.

The by-product of the paper recycling process — sludge — is treated as industrial waste and often landfilled. The amount and nature of the sludge generated during paper recycling is directly related to the type of waste paper being recycled.<sup>17</sup>

#### **5. Plastics**

Plastics are the new kid on the block when it comes to recycling. They are also the new kid on the block in packaging applications. The widespread use of plastics in packaging did not occur until the 1970s,<sup>18</sup> compared, for example, to the steel food container (tin can)

which was developed and used for food processing in the early 1800s.<sup>19</sup> Plastics entered the post-consumer recycling market in the early-1980s, although *in-plant* recycling of scrap plastics was routine among plastics processors from the very beginning of the industry.

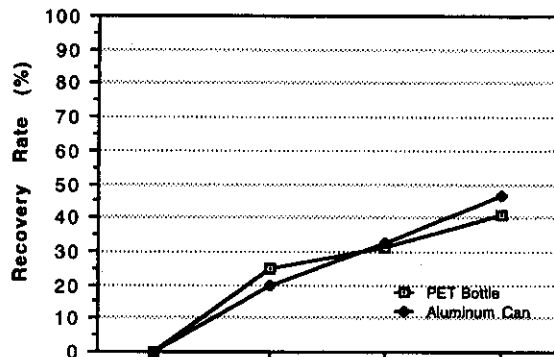
Plastics have become the material of choice for many packaging applications because they are light-weight and shatter-resistant, and because they are uniquely efficient at protecting products in the marketplace.

Like other materials used to manufacture products and packages, plastics recycling has evolved over time, albeit a much shorter period of time. As recycling technology for plastics has advanced, so has the recycling rate for plastics. The polyethylene terephthalate (PET) plastic soft drink bottle offers a good illustration of this linkage.

The PET bottle was first introduced in the U.S. market in the early-1970s. According to the EPA, in 1980 the recycling rate for PET soft drink bottles was zero.<sup>20</sup> During the twelve year period from 1980 to 1992, there were significant advances in the technologies used to collect, sort and process post-consumer PET. As a result, the 1992 recycling rate for PET soft drink bottles reached 40.6 percent.<sup>21</sup> By comparison, the aluminum beverage can was first introduced in the U.S. market in the early-1960s. The EPA reports that in 1970, the recycling rate for the aluminum beverage can was zero. By 1985, the recycling rate for aluminum cans had reached 46.2 percent.<sup>22</sup> Both of these widely used packages experienced steady growth in recycling rates over a period of twelve to fifteen years as recycling

technologies improved and collection programs expanded.

### Aluminum/PET Recycling Evolution



Aluminum Can	1970	1975	1980	1985
PET Bottle	1980	1985	1990	1992

Source: U.S. Environmental Protection Agency, "Characterization of Municipal Solid Waste in the United States, 1992 Update," July 1992.

Most plastics recycling today is accomplished via mechanical technology that has evolved through Stage III (remolding) of the four stages of recycling technology discussed previously in this paper. After post-consumer plastics are collected, they are usually:<sup>23</sup>

- sorted by resin type to enhance quality;<sup>24</sup>
- shredded or granulated to a uniform particle size;
- cleaned of contaminants (food residue, labels) usually in hot water with a mild detergent;
- dried;
- heated and compressed at a relatively low temperature;
- filtered to remove additional solid contaminants;
- forced through an extruder heated to approximately 475° (F) which forms the plastic into pellets; and

- marketed to manufacturers of plastics products and packages.

While this mechanical (remolding) technology has helped to significantly increase plastics' recycling rate over the past decade, and will continue to play a vital role in the future, it is not without some drawbacks. The technology:

- is labor-intensive and, therefore, quite costly to operate;
- requires a relatively clean stream of post-consumer plastics to produce a high-quality, uncontaminated end-product;
- requires separation by resin-type and color to achieve high market value; and
- produces a resin product that has limited markets.

Plastics recycled using mechanical methods are not utilized in most food contact applications unless a barrier is used to prevent direct contact with the food product, or the source of the recycled plastic is strictly controlled. Mechanically recycled plastics may also experience some decrease in performance characteristics — both of these factors limit the range of products that can be produced from mechanically recycled resins.

In addition, some types of post consumer plastics have traditionally proven difficult to market when they are recycled using mechanical systems. However, advanced forms of plastics recycling technology are now being tested, and in some instances commercialized, to increase the capability of

the recycling infrastructure to economically recycle a wide-array of post-consumer plastics into useful products.

Like the Stage IV advanced recycling technologies used for steel, aluminum, glass and paper, these state-of-the-art recycling processes use heat or a chemical reaction to reprocess plastics back to the raw material from which they were made. Plastics are made from crude oil or natural gas.

When post-consumer plastics are recycled using advanced recycling technologies, they yield a variety of versatile and marketable products that are the building blocks from which new plastics and a variety of other end-products are made, including: synthetic fibers, gasoline, heating oil and high-quality lubricants.

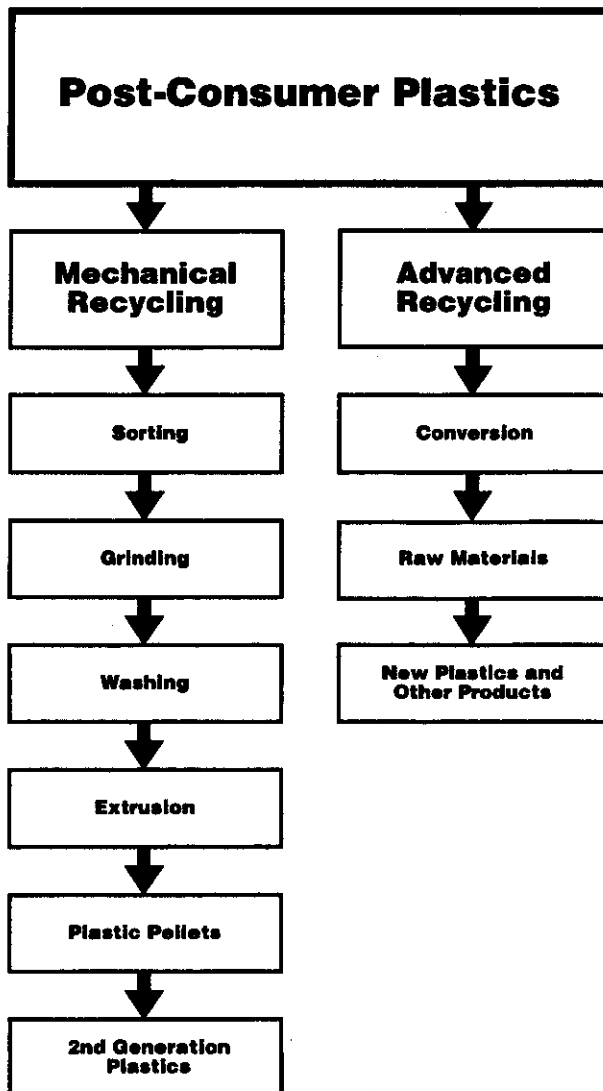
Moreover, advanced recycling technologies are not only capable of recycling a greater variety of post-consumer plastics, but it is hoped that some will also be able to process mixed plastics that have not been washed, or separated by color and resin type — eliminating the need for costly sorting and cleaning procedures. Like all forms of recycling, advanced recycling technologies:

- conserve natural resources (crude oil, natural gas, water);
- reduce waste; and
- produce useful, marketable products (new plastics, fibers, heating oil, lubricants).

Once commercialized, advanced plastics recycling processes have the added advantage of decreasing America's dependence on foreign oil.

## Advanced Plastics Recycling: How It Works

The advanced recycling technologies currently being tested and commercialized for use with post-consumer plastics will augment existing mechanical systems as part of an integrated approach to recycling designed to increase the volume of post-consumer plastics diverted from the waste stream and expand the variety of plastics that are recycled into new and useful products.



Advanced recycling technologies for plastics — as with other materials like steel, aluminum and glass — generally fall into two process categories: chemical and thermal.

### 1. Chemical Processes<sup>25</sup>

One form of advanced recycling technology actually uses wood alcohol to reverse the process used to produce certain plastics (polymers), by reprocessing them back to the building blocks (monomers) from which they were made.

Two special forms of this chemical process, methanolysis and glycolysis, are capable of recycling PET and other so-called "condensation" plastics (polyamides, polyurethanes) back to monomers that can then be purified and used to make the original plastic from which they were recycled, or they may be used in the production of other plastic products.

Several soft drink companies now sell soda in PET bottles produced, in part, from PET that has been recycled using these technologies. In fact, companies that produce new plastics with advanced recycling techniques based on this chemical process have determined that the U.S. Food and Drug Administration (FDA) does not object to the use of their recycled plastics in food and beverage packages.

Post-consumer plastics recycled with traditional mechanical technology have not been used in most food and beverage applications unless a barrier exists between the plastic and the food product, or the source of the recycled plastic is strictly controlled. The FDA has expressed concern that the mechanical recycling process may not remove

all of the contaminants present when plastics are retrieved from the waste stream for recycling.

Methanolysis and glycolysis of post-consumer plastic bottles currently require a clean, relatively pure feedstream.<sup>26</sup> To meet this requirement, used plastics must be isolated by resin type, cleaned and ground. Once these processing steps have been completed for methanolysis, the clean plastic flake is mixed with methanol at elevated temperatures and pressure. This step converts the plastic back to monomers that are separated and purified by distillation. The monomers are then used to manufacture new plastics for a variety of product applications. The excess methanol can be reused to recycle more plastic into new and useful products.

For glycolysis, post-consumer plastic flake is heated with ethylene glycol. This advanced recycling process also produces material that can be purified and made into new plastic.

The resins produced from these two forms of advanced recycling technology have the same properties, performance characteristics and markets as virgin resins, creating the opportunity to develop higher-valued products from post-consumer plastics.<sup>27</sup>

For example, t-shirts manufactured from recycled plastic bottles are now being marketed by a mail-order company headquartered in Brunswick, Maine. The fabric used to make the shirts is made of polyester produced with an advanced recycling technology using a chemical process developed by Hoescht Celanese. The Associated Press reports, "the fabric has the look and feel of high quality cotton-polyester blends."<sup>28</sup>

## 2. Heat Process

A process known as "thermal decomposition," which dates back to the 1500s,<sup>29</sup> is being modernized, tested and commercialized as a form of advanced recycling technology for plastics.

With this process, post-consumer plastics are heated in a recycling unit to about 1000° (F), roughly the same temperature required to melt aluminum. The heating takes place in an oxygen free environment, which prevents the plastics from burning. The plastics are reprocessed and converted back into the liquid petroleum products from which plastics are made. These liquid products are refined and transformed into a wide variety of marketable items including new plastics, synthetic fibers, high-quality lubricants and gasoline.

In addition to liquid petroleum products, this advanced recycling technology produces small amounts of solid carbon and light gases. The carbon can be marketed for use in the production of activated carbon, pigments, rubber goods, and applications in oil remediation and agriculture. The light gases — which are similar to natural gas — can be reused on site.

When integrated with traditional mechanical recycling systems, this "thermal" form of advanced plastics recycling offers a number of significant advantages:

- post-consumer plastics containing high levels of contamination (food waste, labels) can be safely recycled by the technology;

- the technology can recycle mixed or commingled streams of plastics; and
- the technology is a clean environmental process.

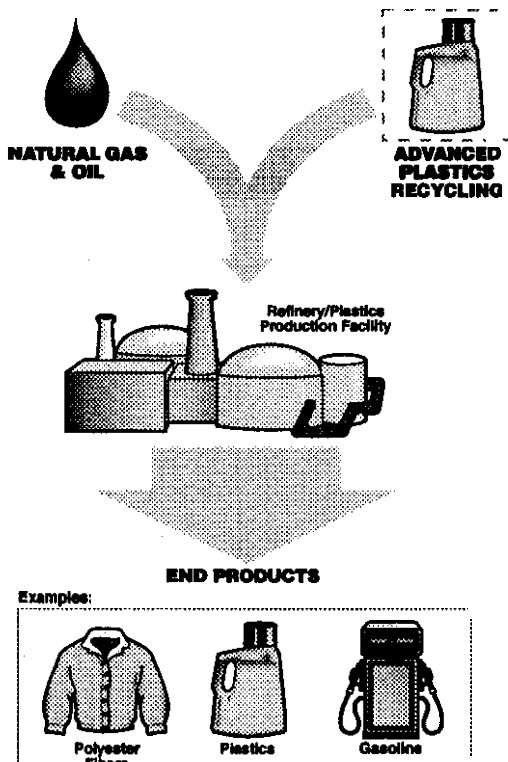
There are several commercial versions of advanced recycling technology currently in operation using the heat process, including recycling programs in Germany<sup>30</sup> and Japan that recycle post-consumer plastics. One facility is using advanced recycling for polyethylene, polypropylene, polystyrene or mixtures of these types of plastics. A U.S. firm, Wayne Technology, is operating an advanced recycling system that recycles mixed plastics.<sup>31</sup>

In May 1993, the American Plastics Council (APC) joined with Conrad Industries,

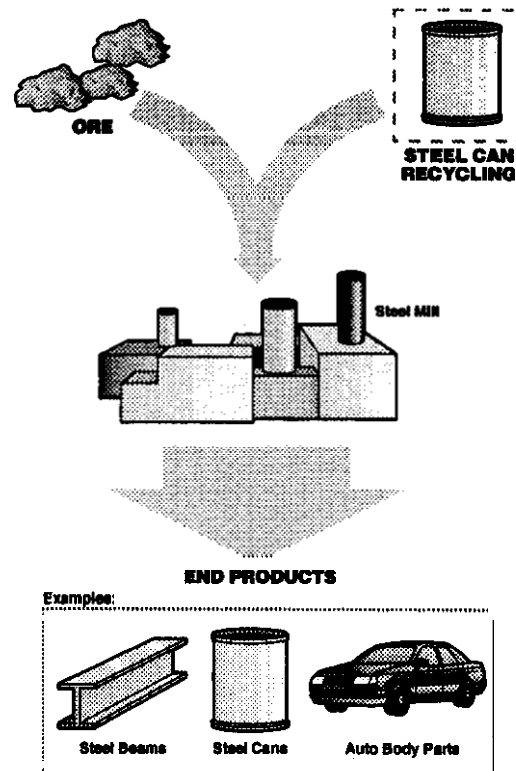
Inc., of Centralia, Washington to demonstrate an advanced recycling system that recycles plastics back into the raw materials from which they were made. The Conrad recycling technology applies heat to post-consumer plastics in a closed unit, free of oxygen. Once heated, the plastics are reprocessed back to liquid petroleum that will be refined to produce marketable products, including new plastics.

The Conrad recycling system is analogous to the recycling processes used for steel, aluminum, glass, and paper that also use heat to convert post-consumer products and packages back to raw materials that are then used to produce new products. Regardless of the material being recycled, these advanced recycling systems conserve natural resources, reduce waste and produce new, marketable products.

## PLASTICS



## STEEL



The Conrad advanced recycling system will be used to augment existing recycling programs in Washington and Oregon, recycling post-consumer plastics currently not widely recycled in those states. Both

advanced and mechanical plastics recycling processes are viewed by the plastics industry "as important elements of an integrated solid waste management system that contributes to resource conservation and waste reduction."<sup>32</sup>

## **Advanced Recycling Technology: The Future**

Using the advanced recycling technologies described in this paper as part of an integrated plastics recycling system depends, in part, upon their commercial applicability. Before these advanced recycling technologies are implemented fully, each must be evaluated based on:

- environmental attributes and impacts;
- economic feasibility;
- regulatory climate; and
- the potential for community involvement.

### **1. Environmental Attributes and Impacts**

All recycling technologies, regardless of the material being recycled, produce by-products that must be effectively managed to protect the environment. The American Plastics Council and its members are committed to quantifying the environmental attributes of all processes associated with plastics recycling.

The advanced recycling technologies described in this paper are believed to be safe, efficient and environmentally acceptable. Research conducted at the Conrad Industries recycling facility shows that the advanced recycling technology used by Conrad is well within environmental standards. Efforts to quantify the environmental attributes and impacts of other forms of advanced recycling technology are ongoing.

### **2. Economic Feasibility**

An important consideration involved in the development of advanced recycling

technologies for plastics is economic feasibility — determined by the difference between the value of products produced compared to the cost of the recycling process itself. In general, recycling methods that lead to higher value products have a greater chance of being economically acceptable.

Processing costs are frequently some of the most challenging for plastics recycling. These costs include collection, transportation and sometimes sorting, purification and bailing steps, depending on the composition of the waste stream and the recycling process that is used.

As mentioned previously, the advanced recycling technology used at the Conrad recycling facility is capable of reprocessing mixed streams of plastics and is able to manage post-consumer plastics that may contain contaminants such as food waste and beverage residue. That means that sorting and cleaning costs are significantly reduced.

For each advanced recycling technique considered for commercialization, the costs of processing must be weighed against the market value of the products that will be produced by the recycling process. Some processing costs may be offset by the savings linked to avoiding landfill tipping fees. Other cost reduction factors might include favorable tax legislation for municipalities and recyclers.

Without these favorable conditions, it is possible that products produced from the recycling of post-consumer plastics may be at a significant disadvantage in the marketplace when compared to the same products produced from raw materials.

All of the advanced recycling technologies highlighted in this paper will have to pass the

“economic feasibility” test if they are to survive in our free-market economy.

### 3. Regulatory Climate

Another important factor that can greatly influence the effectiveness of these new technologies, and their ability to remove plastics from the waste stream, is the regulatory climate. Because the application of these technologies to post-consumer plastics is new and, in some cases, not yet commercially proven, regulations governing recycling could have great impact on their development.

Something as simple as how regulations and statutes define recycling can have a profound impact on the utilization of a specific technology. The definitions cited at the beginning of this paper would recognize the legitimacy of advanced forms of recycling for plastics and other materials. However, an extremely narrow definition of recycling — one that limits the range of products produced by the recycling process — could hinder the application of advanced technologies that reprocess post-consumer plastics and other materials into a wide array of useful items. Should that occur, America’s capacity to recycle used packaging and products could never reach its full potential — valuable natural resources would be wasted and more material would end up at disposal facilities.

For example, if recycling was defined narrowly as a process that converts a container back into a new container, the recycling technologies used for steel, plastics, paper, and to some extent, glass and aluminum, could be placed in jeopardy. Post-consumer steel cans are recycled into raw steel that is not only used for new cans, but

also for auto bodies, construction beams and other steel products. Post-consumer plastic bottles can be recycled into synthetic fiber, a variety of household products, high-quality lubricants, gasoline, as well as new plastic bottles. Waste office paper is recycled into a whole array of different paper products. Post-consumer glass bottles are not only recycled back into bottles, but are also being recycled into glassphalt for road surfacing.

### 4. Community Involvement

An important success factor in any recycling program is the support and involvement of local communities. For an integrated recycling program to succeed, collection programs must:

- be cost-effective;
- be user friendly;
- encourage high participation rates; and
- provide high quality supplies of recyclable materials.

The establishment of local material recovery and recycling facilities reduces collection, sorting and transportation costs. Finally, community participation and involvement is essential to recycling greater portions of municipal waste streams.

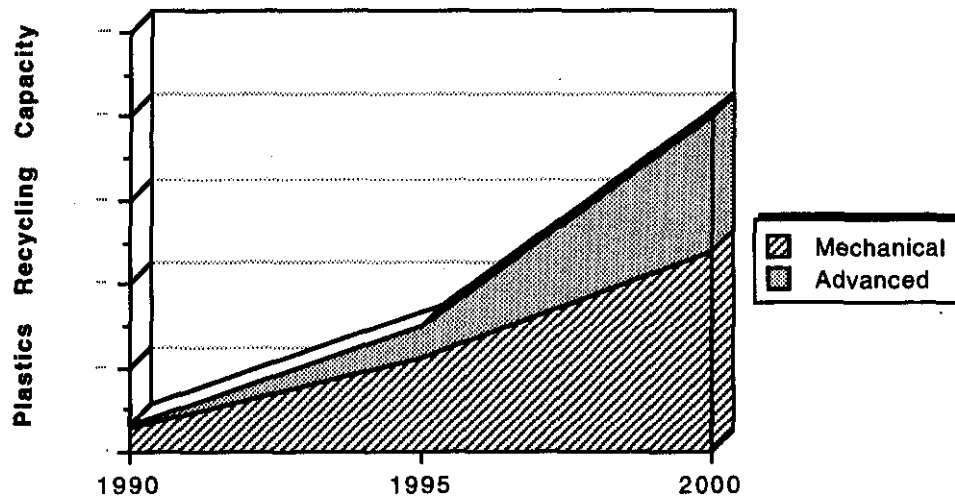
**Advanced Recycling Technology:  
Potential Impact**

While many of the advanced plastics recycling technologies highlighted in this paper are still in a developmental stage, they do offer the possibility of greatly enhancing the capacity of the plastics recycling infrastructure to conserve natural resources and reduce waste. The table below represents one

expert's attempt to project the impact of advanced recycling technologies if they become integrated within the plastics recycling infrastructure in the United States.<sup>33</sup>

For more information about advanced recycling technologies for plastics, write the American Plastics Council, 1275 K Street, NW, Suite 400, Washington, D.C. 20005.

**U.S. Plastics Recycling Projections: 1990 — 2000**



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