CHAPTER D

RESOURCE RECOVERY FROM MIXED SOLID WASTE

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ABSTRACT

This paper points out some of the benefits that can be realized from a mixed waste resource recovery program. The objective of a mixed waste recovery system is to remove as much of the marketable material as is economically feasible from the waste stream. The various technologies used for separating marketable components from the solid waste stream are reviewed. Two of the more promising systems, wet processing and dry processing are described. Resource recovery from mixed solid waste is a technique that is presently experiencing its first large scale, commercial applications. As should be expected, operating problems still exist and need to be solved. Other barriers to implementation such as lack of markets and financing are also discussed. The conclusion is reached that mixed solid waste processing will have an important future in resource recovery efforts when combined with waste reduction and source separation.

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Resource recovery from the solid waste stream can be broken down into materials recovery and energy recovery. This section deals primarily with the techniques used for materials recovery; however, the two processes are closely related and in any comprehensive plan the system selected for energy recovery will limit the alternatives available for materials recovery and vice versa.

Present materials recovery programs concentrate on extracting ferrous and non-ferrous metals, glass (either mixed color or sorted) and paper. In addition, fuel substitutes or converted energy products are sometimes taken from the organic portion of what remains. The goal of materials recovery processes is to maximize removal of the economically viable products from the waste stream in a sequence that optimizes product quality and economic feasibility. The key to economic success of the process is choice of the proper processing scheme. Such a choice will in each case depend upon local landfill availability, the present collection system, plant location, location of energy consumers, recycled materials markets and resource recovery priorities of the service area.

An advantage of a materials recovery system is that it can be easily integrated into existing waste collection and transfer systems. Most systems can reduce the residual fraction of the solid waste input going to landfill to 10% by volume of the original stream. In some cases developers of high temperature thermal processes claim 100% of the throughput can be converted into products with positive market value (EPA 1977). Another advantage is high public acceptance of recovery programs and 100% participation.

In contrast to source separation programs, a mixed waste recovery system requires no change in life-style of the populace and all materials in a regional waste stream are involved and processed by the system. One of the primary advantages of materials recovery is that it can help to lower disposal costs. As energy costs rise, the energy recovered from solid waste increases in value as do other materials such as aluminum, ferrous metals and glass that require more energy to produce from virgin materials than to recycle. As the value of these recoverable materials increases, it becomes more and more desirable to remove them from the waste stream. Revenue derived from energy and materials recovery lowers disposal costs accordingly (see Table 1).

TABLE 1

Potential Revenue from Materials Recovery

Component	Percent Solid Waste[1]		Recovery Efficiency[2]	Market Value[3]	Potential Revenue/Ton
Aluminum	.7		50-75%	$300/ton	$1.05-1.57
Glass	10.8		50-70%	$5-20/ton	.27-1.51
Ferrous Metal	7.3		90-98%	$20-40/ton	1.31-2.86
Paper	43.2	RDF*	50-70%	$13.60/ton to $27.20/ton[3]	5.52-15.46
Plastic	4.5				
Other	33.5				
			Range Potential	Revenue/ton	$8.15-21.40
				Revenue/MT	$9.13-23.97

[1]From Environmental Protection Agency's Fourth Report to Congress

[2]TBRPC 1976, Skinner 1977, George Savage 1978, oral communication

[3]Assumes RDF 6,800 BTU/lb. and RDF value $1.00 and $2.00 per MMBTU, TBRPC 1976

*Refuse derived fuel

Another benefit of materials recovery is that it can stimulate the formation of a whole new industry - the resource recovery industry - and along with it bring in secondary industries and jobs that will utilize the recovered material.

Most mixed waste materials recovery systems under consideration and construction involve relatively complex, capital-intensive designs. The costs of these vary from $5,000 to $50,000 per ton of daily processing capacity depending on the type of plant, plant capacity, types of materials recovered and other factors (EPA 1977). Economies of scale seem to be very important in this kind of high technology, centralized processing so that many of these systems may be restricted to larger cities or regional applications. The high initial capital cost of most of these systems requires that sophisticated planning, marketing and management be undertaken so that financial risks are kept to a minimum (Tampa Bay Regional Planning Council, TBRPC, 1976).

Availability of markets is a critical question to be answered before establishing any materials recovery system. Presently most systems are designed around existing local markets. What are most desirable are long-term contracts that are adjustable to keep pace with fluctuations in market prices for the various materials recovered.

Other advantages of resource recovery are harder to express in dollar values per ton. In the Bay Area the environmental enhancement of reduced landfill would be a major benefit along with increased recycling of resources and economic development.

Technologies

City planners and managers who must select resource recovery systems have many designs to choose from. One of the most important criteria for such systems is reliability. The solid waste stream does not stop when a plant is shut down for repairs and long-term contracts for energy and materials are not likely obtainable if systems are unreliable. For this reason backups and redundancy must be built into a system that is already proven dependable (Hendrickson 1975). A plant built to last twenty years must also be flexible, since markets, waste composition, and other important factors change. In materials recovery the present American trend is towards modular systems. Most systems are designed so that a module (e.g., for glass recovery) can be added on to the existing system when extraction of that material becomes cost effective and a market is present (TBRPC 1975). Flexibility also means that seasonal fluctuations in the waste stream can be taken care of and that increased volume as the result of increased local population can be managed.

Most of the techniques available for materials recovery are mechanical processes or adaptations from the mining or paper industries. Their basic purposes are to maximize the percentage of available resources reclaimed while minimizing the impurities so that the product will have the highest market price possible.

There are two broad categories of systems to be considered for recovering the various components from the waste stream. These are wet and dry processes. Both begin by reducing the size of the incoming waste through either shredding (dry process) or hydrapulping (wet process). The result is a dense homogeneous mixture with a controlled particle size that can then be efficiently processed (Rodgers and Hitte, 1974).

Paper Fiber Recovery

Paper fiber recovered is usually of low quality as the result of the mixture of various fibers present in solid waste (cardboard, milk cartons, packaging papers, etc.). A module of the wet process can upgrade the quality of paper fiber taken from the solid waste stream if required. However, this is not necessary for the current, low quality building paper market (Arella 1974). In the dry process the recovered fiber quality is low and can either be used for recycled paper or can be left in the refuse derived fuel (RDF) component where it is valuable due to its high BTU content (up to 8,000 BTU/lb., EPA 1977). Dry processing for paper involves a series of air classifiers and screens. After shredding, the solid waste is carried into a primary air classifier where the heavies, or dense particles fall through the bottom, and the lights, or less dense particles, are blown out the top. This light fraction consisting of paper, plastic and other light material can then be further air classified and screened to remove dirt and small particles until the desired separation of paper from plastics and other debris is achieved (Boettcher 1972). Wet processing will be described separately.

Ferrous Metal Recovery

Ferrous metal is recovered by a module that can be incorporated into nearly all energy and materials recovery systems. The technology, which is simple and readily available, is based on magnetic attraction of ferrous metals. Ferrous recovery, because of its simplicity and the number of available scrap markets, is already commonly practiced at many transfer stations and landfill sites (Levy, Rigo 1976). Magnetic separation usually follows the first stage of shredding; however, in more sophisticated systems a second magnetic separator is employed at the end of the line to catch any ferrous materials that passed through the first stage (see Figure 1). The other source of ferrous metals are the large bulky items that are often hand separated at the beginning of the recovery process to protect size reducing equipment.

Two kinds of magnetic separators are most commonly used: suspended and head pulley types (Drobny, Hull, Testin 1971; Levy, Rigo 1976). Suspended separators are positioned over feed conveyors and pick up ferrous materials and move them over to another conveyor. The ferrous metal is often contaminated with paper, so a head pulley separator is commonly used for secondary separation. The head pulley system causes magnetically attractive fragments to stick to the conveyor head while other materials are released forward of the head. Recovery efficiencies of between 90-98% are reported for ferrous metals thus removed (TBRPC 1976, EPA 1976). The three principal ferrous metal markets involve re-use for de-tinning, steel production and copper precipitation. Each of these markets has different requirements for physical characteristics and contaminant limitations. Hence, the intended market must be determined before final design of the system so that materials meeting the proper specifications can be produced (Hendrickson 1975).

Aluminum and Glass Recovery

Recovery of aluminum and glass normally occurs after paper, ferrous metals and combustible light organics have been removed. This fraction, often called the heavies, includes along with aluminum and glass other nonferrous metals, stones, dirt and residual heavy organics such as food, wood and rubber (Levy, Rigo 1976).

Aluminum is difficult to extract because it has no unique physical properties with which to isolate it from the waste stream and it is a small constituent (less than 1%). Its high value as a scrap, however, makes it a desirable component to recover. The market value for a ton of glass is much less than that for aluminum, but it represents about 9% of the waste stream, which makes its value per ton of solid waste equal to the value of the aluminum present. The major

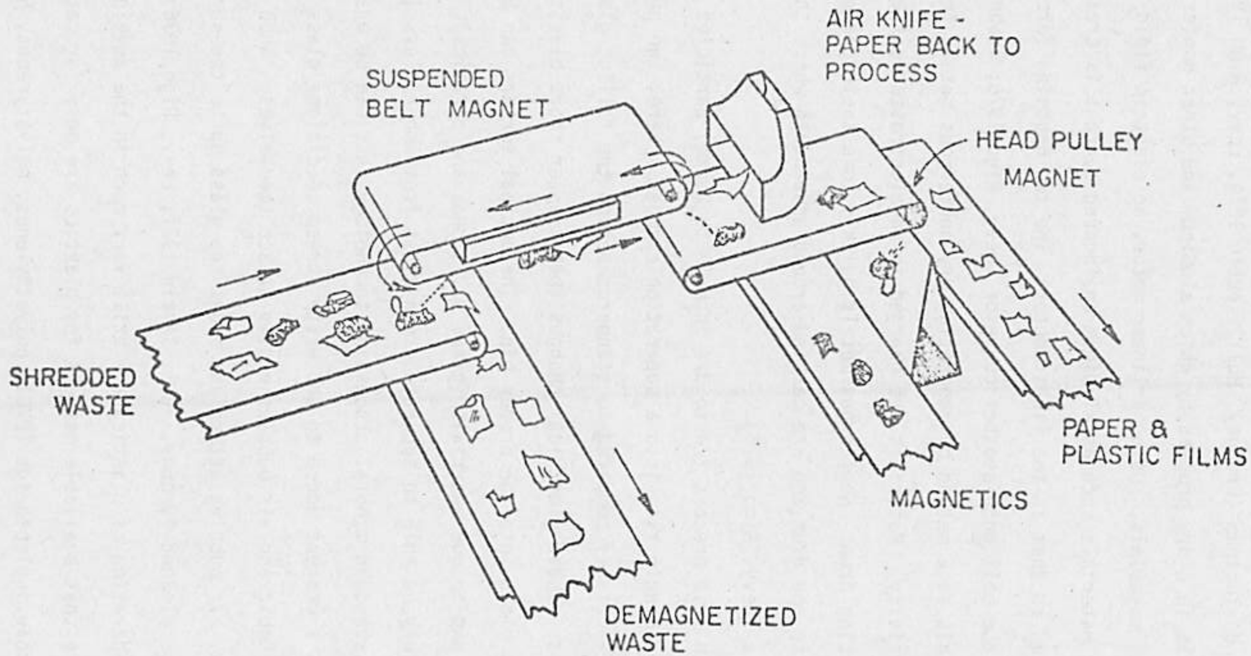

Figure 1. Magnetic separation of ferrous metal using both suspended belt magnet and head pulley magnet.

(Levy, Rigo 1976)

obstacles to recovering glass are the removal of contaminants in order to meet strict industry quality standards and separation of various colors. Some of the unit processes for glass and aluminum recovery are the following:

Heavy media separation - In this process a fluid with a pre-determined specific density is created using heavy minerals so that materials fed into the solution either sink or float. Separation is accomplished by using multiple cells that isolate material of desired specific density. This process can be used for both glass and aluminum (Drobney, Hull, Testin 1974; Levy, Rigo 1976).

Eddy current separation - This is a dry process by which aluminum and other nonferrous metals can be separated from non-conducting materials. Using a linear motor, an electric field is produced along the conveyor. In conducting materials such as aluminum an induced current is created by the field which develops a force opposed to that in the linear motor. The two opposing forces then cause the conductor to be knocked off the belt onto another conveyor (Levy, Rigo 1976; Drobny, Hull, Testin 1971).

Electrostatic separation - This is a method of separating dry nonferrous metals from the waste stream based on differential conductivity. Materials are charged in an electrostatic field and then are dropped onto a grounded rotating drum. Nonferrous metals quickly lose their charge and drop off the drum, other materials cling to the drum and are carried around underneath where they are removed and separated from the metals (Levy, Rigo 1976).

Optical sorting of glass - In this process 1/4 to 3/4 inch (6 to 20 mm) particles of mixed colored glass known as cullet are fed single file into a separation chamber. Here, two photocells view the glass and differences in reflectivity compared to standards behind the falling glass cause changes in voltages of the photocells. These electrical changes then trigger short blasts of compressed air that deflect the falling glass into the proper bin. The optical sorters can be set up to differentiate between clear and opaque materials (glass vs. stones and ceramics), clear glass and colored glass, and may possibly be able to separate green glass from amber glass (Levy, Rigo 1976).

Froth flotation - This is a standard mineral processing technology that can be adapted to glass separation. In this process a reagent added to the waste stream conditions glass objects so that their surfaces become hydrophobic and air bubbles easily attach themselves. When the waste is fed into a water-filled tank, air bubbles attach and float the glass up to the surface where it can be removed by skimmers and be cleaned (Drobny, Hull, Testin 1971; Levy, Rigo 1976).

Plastics - Techniques for separation of plastics are still very much in the developmental stages. The problems to be solved are that available markets for plastics are only for materials separated into generic types such as polyvinylchloride (PVC), polyethylenes, polystyrenes, Nylon and others. Present technologies such as air classification, electromagnetic separation and froth flotation have been tried but the recovered materials are not of high enough quality for present markets (Combustion Power Company, Inc. 1974).

Front-end materials recovery systems - The previously described technologies are usually integrated into two basically different systems. One process, the wet process, has been tested at the EPA's 150 ton per day (TPD) [140 metric ton per day (MTPD)] Franklin, Ohio demonstration project. This pilot project uses a system developed by the Black-Clawson Company to recover paper, ferrous metals, glass, and a combustible fraction from the city's solid waste and has cut the volume of materials going to land fill by 95% (Arella 1974).

The flow chart (see Figure 2) shows the components of the wet process. The waste first enters the hydrapulper, which is a twelve-foot diameter tub with a high-speed cutting blade in the bottom that is driven by a 300 horsepower motor. Water is mixed with the waste and soft, or brittle materials are ground into a slurry that passes through a perforated plate beneath the rotor. Large pieces of metal and other non-pulpable materials are thrown up and out of the pulper to the junk remover where they are collected and ferrous materials are magnetically separated. The remainder of this fraction is landfilled; however, investigations are being made to determine feasibility of nonferrous metal recovery from the remainder. The slurry leaving the bottom of the hydrapulper consists of nearly all the paper and organic materials in addition to glass, small pieces of metal, ceramics and much of the aluminum. This slurry then enters the liquid cyclone where dense materials such as the glass, aluminum, metal, ceramics and stones are separated from the light fibrous combustible materials by centrifugal force.

The heavy fraction is sent to the glass and aluminum recovery sub-system developed by the Glass Containers Manufacturers Institute. This system uses mechanical screening and sorting to remove contaminants and ends up with an aluminum-rich stream and a glass-rich stream which is optically sorted. Combustible extraneous materials are sent to the incinerator for combustion.

The light fraction produced by the liquid cyclone goes to the fiber recovery system adapted from the paper industry or alternately, as in the figure,is de-watered and combusted for energy recovery. At the Franklin plant the longer, more valuable paper fibers are mechanically removed by screens from the shorter paper fibers which are contaminated with coatings, rubber, food waste, yard waste, and very small pieces of dirt and sand. This remaining fraction is sent to the incinerator for combustion.

The Franklin plant has proven very reliable and required maintenance has been significantly less than that required by present-day dry processes. This is probably because much of the technology has been perfected in the paper industry from which it was borrowed. Other advantages of the wet process are that the dust problem, inherent in dry shredders is eliminated and the problem of explosions and fires is solved by the water. If raw sewage must be dealt with the wet process seems especially attractive, since it is possible to combine sewage sludge with the non-recovered combustible solid wastes, de-water, and then combust the two efficiently in a fluid bed incinerator. This could increase energy recovery and eliminate the need for costly sludge digestion and disposal equipment.

As of March 1977, the Franklin plant was recovering ferrous metals, paper fiber and color-sorted glass with recovery of aluminum anticipated soon thereafter. The proportions of these materials in the

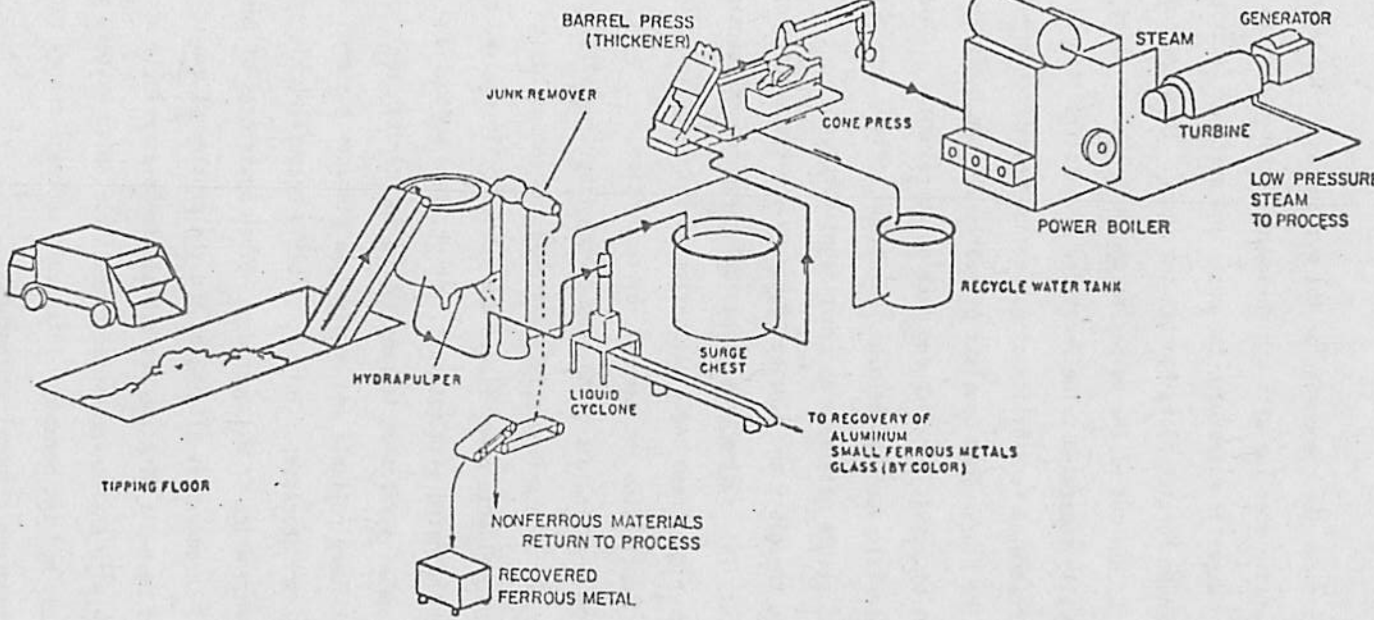

Figure 2. Wet Processing for Materials and Energy Recovery

solid waste stream and the recovery rates and efficiencies are shown (Table 2). The economics of the Franklin plant are good. However, a larger plant would have added reserve from energy recovery to make disposal costs even less. One disadvantage of the wet process is that the fuel recovered has a much reduced heating value due to the high moisture content when compared to dry processes (Arella 1974).

TABLE 2

Recovery Efficiencies

Material[1]	Wet Process[2]	Dry Process[3]
paper fiber	49%	40%
RDF	34%	40-60%
ferrous metal	94%	90-98%
glass	50-60%	50-70%
aluminum	50%	50-75%

[1]Materials recovered by the two processes differ in quality and therefore in market value. For instance, the wet process removes long higher grade paper fibers than does the dry process.

[2]EPA 1977; Arella 1974.

[3]George Savage, personal communication, TBRPC 1976.

Dry Processes

There are many different dry process materials recovery plants in operation, most using arrangements of the same basic elements; however, few have been demonstrated on such a large, commercial scale over as long a period of time as the Franklin, Ohio wet processing plant. Some of the important dry systems have been developed by the Bureau of Mines, the National Center for Resource Recovery (for New Orleans); Ames, Iowa; Hempsted, New York; San Diego, California; and in the Bay Area the Cal Recovery System developed by members of the Department of Mechanical Engineering, U.C. Berkeley at the Richmond Field Station.

The Cal system has been successfully demonstrated at a capacity of 4 tons/hr. A flow chart for this system is shown to make explanation easier (see Figure 3). First the solid waste is fed by conveyor into the primary size reducing shredder. The size of exiting material can be controlled through the use of different grate sizes. This control is necessary to optimize the efficiencies of different modules in the system.

After size reduction the waste is led into the air classifier where the lights, comprising approximately 70% of the stream, are separated from the heavies, 30%. The air classified lights are then carried to a cyclone where the air is removed and the material is deposited on a conveyor. This material can be sold as low quality waste paper stock or as low BTU refuse-derived fuel (RDF) yielding 5200 BTU/lb. By simply passing this fraction through a trommel screen (a rotating drum with 3/8" holes in it), much of the inert

DRY PROCESSING

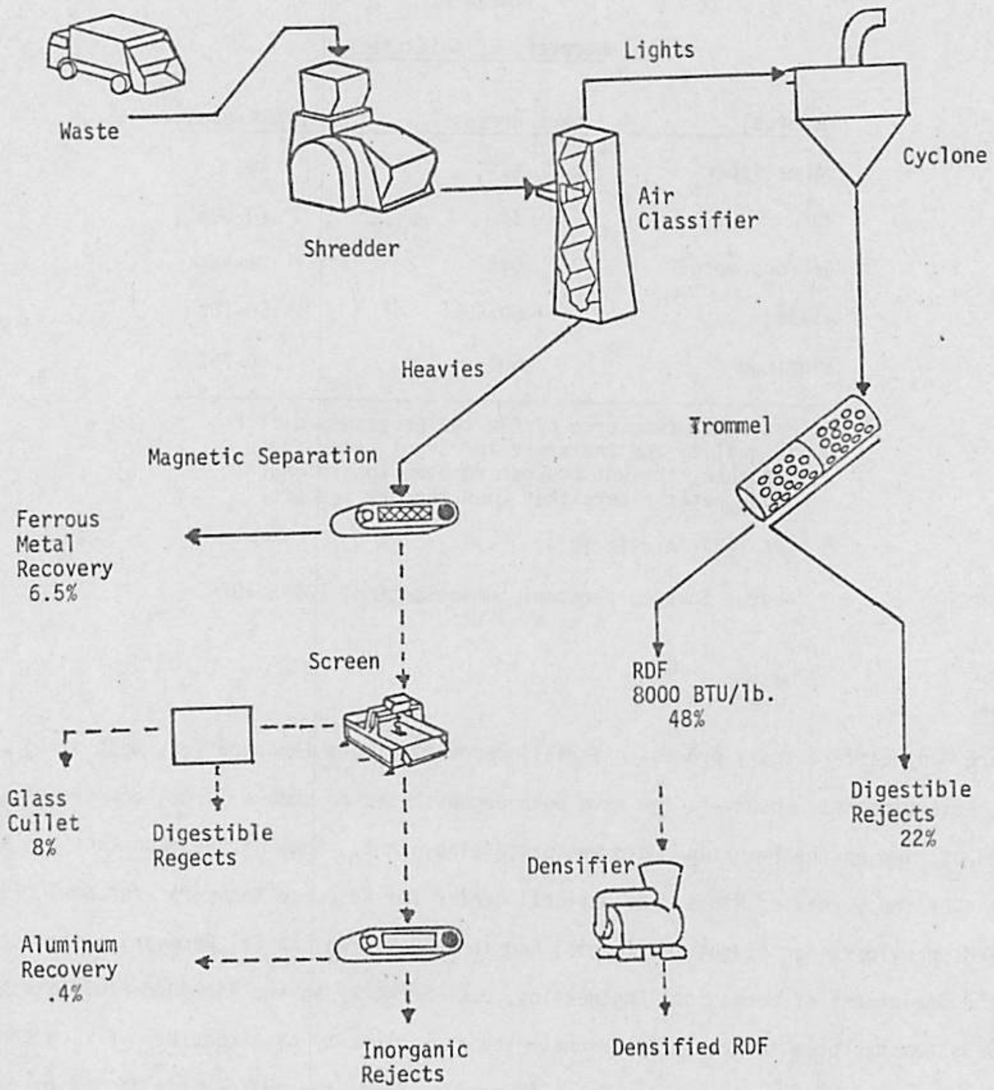

Figure 3. This simplified flow diagram illustrates the components of the Cal Recovery System. Approximate values for recovered materials, as a percentage by weight of incoming waste are given. The dotted lines indicate optional recovery modules.

noncombustible part of the light fraction can be removed and a higher quality wastepaper or RDF fuel (8000 BTU/lb.) can be produced (see Section IV, Chapter A).

The heavy fraction of the air classified solid waste contains most of the ferrous metal, glass and aluminum. This fraction is first relieved of its ferrous components through magnetic recovery, and then is passed through a module which separates the glass fraction. Currently aluminum is not recovered; however, any of the previously described technologies could be used, depending on which was most cost-effective. Approximate recovery efficiencies for the various materials are given in Table 2 (Savage, Diaz, Trezek 1975).

Strong points of the dry process seem to be its flexibility and the ease with which additional modules can be added on when markets and economics permit. Not having to use water for the process is an advantage and probably a necessity in some areas. The dry process is also extremely flexible in the type of fuel product that it can produce and is therefore more adaptable to energy recovery schemes such as pyrolysis, fluid bed combustion and water wall incineration than is the wet process. These and other advantages inherent in the dry process have combined so that a great majority of the communities with recovery plant construction underway or in advanced planning have selected some form of dry processing for their materials recovery (EPA 1977).

According to the EPA's Fourth Report to Congress on Resource Recovery and Waste Reduction, the most important new developments in materials recovery relate to the fact that several large, new commercial facilities have recently begun operation. Among these are included the New Orleans and Baltimore plants, both of which became operational in 1976 and are designed to recover ferrous metals, aluminum and glass. These facilities will provide the opportunity to better evaluate resource recovery technologies and the characteristics of the recovered materials. Another important development is the establishment of reasonable standards and specifications for the recovered materials (EPA 1977).

Complications in Implementation of Mixed Waste Processing

Nearly all the mixed waste separation systems presently being considered are capital-intensive projects, that is, they require large sums of capital and long-term financing. Before any city or private industry is willing to invest in this kind of a venture, many difficult problems must be solved. One of the first considerations is whether the available technologies are proven and reliable on a commercial scale. Then reliable markets for recycled materials must be found within economical transport range. Once these problems have been studied net processing costs per ton of waste received can be estimated and compared with other solid waste disposal options.

Additional less quantifiable questions of social importance also need to be considered. Pollution effects from energy recovery programs, solid waste transport systems, and continued landfilling are among the problems that need to be studied. Health and safety factors associated with increased handling of solid wastes, a complicated mechanical separation process and additional air pollution from RDF combustion should be considered. One other important question concerns employment and the number of jobs an energy and resource recovery industry would create as compared to other possible options (TBRPC 1976; EPA 1976).

Conflicts between Mixed Waste Recovery, Source Separation and Waste Reduction

The economics of mixed processing facilities could be seriously affected by source separation and waste reduction programs within the service area. These programs could significantly reduce the quantity of recoverable materials in the waste stream and thereby reduce a recovery facility's revenue. Because all three programs may be necessary, anyone planning a recovery facility must analyze how source separation and waste reduction could affect the anticipated revenues of a resource recovery facility.

A recent estimate based on a number of assumptions concerning composition of the waste stream, technology performance, costs and recovered materials market values came up with the following conclusions: The impact on revenue of paper separation programs, considering the present recovery rates, would be small, much less than $1/ton changed value of received waste. This is especially true if the service areas could be expanded. The effect of beverage container removal from the waste stream could be to make removal of other sources of aluminum and glass unprofitable, causing an increase of up to $1.5/ton in disposal costs. Both of these changes were considered relatively small, particularly when compared to the uncertainties relating to market price, system performance, and systems costs that already exist in resource recovery economics.

The possibilities exist that materials markets and recovery technologies might develop to the point where the impacts of separation and reduction could be significant. The possibility and effects of this were not felt to be great enough, though, to warrant restrictive contracts prohibiting municipalities from source separation and waste reduction programs. The best mechanism for guarding against this complication is a flexible recovery system where the inevitable risks and benefits are shared between local government and private owners and operators (Skinner 1977).

Conclusion

Mixed waste resource recovery is a technique that is just beginning to emerge from its developmental and pilot plant stages. Problems have been encountered with most facilities, but surely these are to be expected. Currently the most reliable and economically feasible systems appear to be dry processes that produce some form of RDF for energy recovery in a waterwall incinerator. Many technologies show promise and various modules for materials recovery need to be further developed so that they become more cost effective than at present.

As an option for dealing with our solid waste problem, mixed waste separation has its place along with source separation and waste reduction. The last two have important advantages. However, we will never reduce our garbage to zero and participation in source separation will never approach 100%.

To institute a materials and energy recovery system extensive planning is required to hurdle the many barriers involved. In the Bay Area, ABAG can assist in the implementation of resource recovery in several ways. In the important area of markets they can help by locating, promoting and researching new and existing market possibilities for recycled materials from the region. Despite the many political and institutional barriers that exist to multi-county and regional solutions to the solid waste problem, ABAG can propose and assist in planning regional solutions that take advantage of economies of scale involved in materials recovery plants. A first step in preparing for a regional solution is to locate and standardize transfer stations so that efficient regional truck or rail haul could be developed. Such a scenario could be developed at least as a guide for city and county planners to consider.

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