RESEARCH NEEDS IN WASTE UTILIZATION

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ABSTRACT

Institutional issues are recognized as being the major obstacles to the establishment of resource recovery facilities. However, it is suggested that by addressing critical technological problems and pre-processing aspects associated with waste utilization, implementation of such facilities may be facilitated. General areas in need of further research and development are identified and some specific tasks outlined.

INTRODUCTION

It is generally accepted that institutional issues are the primary constraints to the establishment of resource recovery plants. Market uncertainties and economic and legislative restrictions associated with utilization of products recovered from waste render implementation of such facilities extremely difficult. Additionally, the lack of a sufficient number of successfully operating models lends an aura of skepticism towards resource recovery itself. The purpose of this paper is to review technological and pre-processing problems associated with resource recovery. Areas of R&D need in waste utilization are identified and specific tasks outlined.

R&D CONSIDERATIONS

In view of the accelerated activity in energy and resource conservation, it is particularly appropriate to question initially whether research in this field is actually addressing critical needs. It is equally important to ensure that R&D is being directed not only with an eye towards the short range (20 years), but for the long term as well. The use of a waste material for a purpose considered today may prove to be of far less value (within a period of one generation) than for some other purpose. Many examples may be cited, including the following:

(1) Agricultural wastes for animal feed versus their use in energy recovery processes or as raw material substitutes for petroleum in the manufacture of plastic and resins [1],

(2) Cellulosic wastes for enzymatic conversion to glucose [2] versus for hydrogenation to oil [3], and

(3) Municipal solid waste for fuel versus pyrolytic processing and subsequent conversion to fuel, methanol and other products.

The examples above represent dilemmas in resource recovery. Adding to the complexity of having to make choices between pursuing R&D in different technologies is the difficulty of adequate technology transfer, and the fact that innovations in resource recovery are being made at an exceedingly rapid rate. Most critical is that legislation has not kept pace with new developments in this field and does, in some instances, retard the implementation of new facilities. Examples include legislation which provides disincentives to use of secondary materials through
(1) discriminatory processes, e.g., higher freight rates for secondary materials than for raw materials;
(2) total prohibition of reuse, e.g., use of recycled polyethylene milk bottles in the manufacture of agricultural drainage tiles [4], or of that and other recovered materials in food packaging.

The point being made here is that although we are suggesting in this paper a number of R&D needs, one must, however, acknowledge that the context within which these suggestions are made is immediate and relatively short term.

In spring, 1975, the MITRE Corporation, under contract to the Energy Research and Development Administration, conducted a study [5] aimed at identifying R&D needs in waste utilization, including pre-processing. Agencies, individual researchers, and private and other organizations working in the field of resource recovery were asked to comment on a prepared list of potential areas and specific topics for research in resource recovery. The following section discusses some of the critical points on that list.

R&D NEEDS IN WASTE UTILIZATION

A blanket listing of potentially fruitful topics for research, while having the advantage of being comprehensive, often obscures the relationship between individual topics and poses problems in presentation. This sometimes leads to duplication of effort and suboptimal use of budget, manpower and equipment. It is, therefore, desirable to somehow categorize R&D needs such that maximum use may be made of available resources. In this discussion R&D needs in waste utilization are broken down into

(1) Pre-processing Issues, and
(2) Waste Utilization Processes.

Each of the two classifications is described in the following section. (A more detailed categorization of technical R&D needs would also include Marketing and Environmental Issues.)

PRE-PROCESSING ISSUES

Pre-processing issues are concerned with:
(1) the availability of waste materials for reuse;
(2) the condition of wastes prior to reuse;
(3) treatment before processing.

Availability of Waste Materials for Reuse

Waste materials under consideration are municipal solid waste, agricultural (and forestry) wastes, and industrial solid waste. While reasonable estimates of total waste produced can be made, little work has been done on the availability of these wastes for processing. The occurrence of municipal solid waste in large concentrations renders these wastes particularly suitable for central processing, especially in large urban areas. However, in more rural locations, communities must pool their wastes in order to achieve economies of scale. The question of transportation cost thus becomes a major factor in determining the feasibility of implementing a resource recovery facility. Linear programming models used to site transfer stations and predict haul costs should be greatly encouraged, since they provide valuable information to the public official who must then "sell" the system to his constituency. A number of such models have been developed; one of these was recently used in the planning of the Northeastern Massachusetts Resource Recovery Facility [6].

Industrial wastes of significant value are currently being used in industry and cannot always be considered available for central processing. Typically, specialty fuels such as bagasse, coffee grounds, rice hulls and bark are combusted to raise steam. The usual high moisture content of these wastes results in a combination of suspension burning with the balance of burning on a grate to achieve maximum volume and weight reduction. Since in some regions the establishment of a resource recovery facility will depend upon having the commitment of the industrial waste stream, quantification of these wastes is essential. Studies should be conducted on an industry by industry basis to update some of the S.I.C. waste generation figures presently in general use. The EPA is currently in the process of satisfying this need and has published figures relating to the chemical industry.

Agricultural and animal wastes present special problems primarily because they are difficult to collect, except in the case of confined feedlot operations. And, while it is known that modest quantities of forestry residues exist, the costs of hauling them from steep slopes and other inaccessible areas prohibit their retrieval and reuse. Perhaps the answer lies in developing new machinery capable of forging through such inaccessible areas.
Waste Condition Prior to Reuse

It is virtually impossible to control the composition of materials appearing in the solid waste stream. Thus, it is not uncommon to find materials in the waste which, unless removed prior to processing, would be particularly troublesome to processing equipment. In municipal refuse items such as aerosol cans, explosives, links of cable and various chemicals, may damage shredders and other processing equipment and are potential sources of explosions. Other discards such as tires and rugs have been known to jam equipment resulting in increased downtime. Identification of those waste constituents which may be particularly difficult to process would provide manufacturers with a basis upon which additional research could be performed to increase the availability, efficiency and reliability of processing equipment.

In addition, certain energy recovery systems (e.g., anaerobic digestion) are extremely sensitive to waste feedstock characteristics. That is, a small amount of certain materials such as heavy metal salts are toxic to the bacteriological medium and may upset the biochemical equilibrium [7]. In such processes, extreme care must be taken to prevent the entrance of these materials into the system.

Treatment of Wastes Before Processing

Many waste materials, when processed on an as-received basis, do not readily lend themselves to energy recovery. For example, excessively wet wastes are not amenable to efficient combustion and burnout if not designed properly. Also, certain organic and agricultural wastes have fiber characteristics whose structure reduces the cellulose available from biodegradation. This decreases gas yields in anaerobic digestion and glucose yields in enzymatic conversion, and results in a greater quantity of wastes requiring disposal than would otherwise be realizable.

Work performed to date on improving the processability of waste materials has been severely limited primarily by lack of good engineering. Some experience has been gained in drying wastes and experiments have been conducted in heat and chemical treatment of organic wastes to improve digestibility [8]. Additional support of R&D in this area may produce the technology required to render a waste feedstock more amenable to energy recovery.

In almost all energy and material recovery processes it is necessary to reduce the size of the waste particles in order to homogenize the waste stream and make it amenable to magnetic separation, air classification and materials handling.

Size reduction equipment is available in a wide range of types and capacities from many manufacturers. However, the equipment used to size reduce solid waste has generally been adapted from equipment designed to handle other materials. Furthermore, current methods of size reduction are characterized by high capital and operating costs and high power consumption. And, as the required waste particle size decreases, power consumption and costs increase. Innovative methods of size reduction should be researched to enable size reduction of waste materials to be performed more economically and at lower power consumption rates. In addition, the extent to which shredding is required should be investigated for energy recovery processes currently under consideration.

WASTE UTILIZATION PROCESSES

An abundance of information concerning commercially available energy recovery technologies and operational facilities is in general circulation. Much of the information is of conflicting nature, particularly reported operating and maintenance costs, and system efficiencies. One major problem has been that these systems have not been examined on a common basis, and, as a result, a direct comparison of competing technologies cannot be made. It is appropriate at this time to conduct a comprehensive study, incorporating information presented in previous reports, to assess competing, presently available energy recovery technologies. A major effort should be made to reduce information on costs and efficiencies to a common denominator.

The brief descriptions provided in the following sections will isolate R&D needs associated with selected waste utilization processes.

Waterwall Furnace Incineration

Despite the success of this technology, several problems have yet to be completely resolved. Key topics for further research are:

(1) Improve operating procedures at large-scale facilities.
(2) Improve response to load variance. Both the time-varying nature of waste input to the facility and the heterogeneous character of wastes (particularly municipal solid waste) complicate the uniform or specified demand for steam or electricity. Backup facilities for burning fossil fuels may be required to meet customer steam demands. Improved process controls (e.g., of temperature, pressure, and feed rates) could reduce the reliance on fossil fuels.

(3) Extend operating life of boiler tubes. Fly ash and slag buildup on boiler tubes, and HCl from the combustion of plastics, cause corrosion on tube surfaces. Substitution of carbon steel tubes by chrome moly tubes may partially relieve this problem.

(4) Improve the overall efficiency of Electrostatic Precipitators.

(5) Encourage operator training.

Dry Shredded Fuel Preparation Systems

Many of the R&D needs under this section will be discussed under materials recovery. In summary form, key tasks for further research are:

(1) Improve equipment separation efficiency.
(2) Determine preferred particle size and sequence of unit operations.
(3) Improve materials handling systems.
(4) Improve storability and transportability of fuels.
(5) Investigate characteristic of fuels.
(6) Investigate effects on boiler operations and atmospheric emissions.

Pyrolysis

With about a dozen variations of pyrolysis systems under development and the possible production of either an oil or gas product, pyrolysis is one of the more promising waste-to-energy technologies.

Research tasks which address key issues common to most pyrolysis systems are the following:

(1) Develop design parameters for pyrolysis reactors.
(2) Determine preferred particle size.
(3) Investigate the means of supplying heat to the reactor.
(4) Improve the quality of resulting energy products.
(5) Experiment with various types of wastes.
(6) Explore environmental impacts.

Anaerobic Digestion

Experiments have shown that sewage sludge, animal manures, and combinations of these can be digested anaerobically to product methane. Anaerobic digestion of municipal solid wastes either alone or in conjunction with sludges is in the pilot stage. Further work is required in the areas of:

(1) feed preparation, including size reduction and the separation of the digestible form the undigestible fraction;
(2) improving digestibility of wastes and mixtures of wastes;
(3) developing design parameters from anaerobic digesters, such as solids loading, retention time, and digester temperature, with particular attention to scale-up problems;
(4) investigating effluent dewatering and ultimate disposal of the undigested residue;
(5) improving the gas preparation technology (including the separation of carbon dioxide from methane and the elimination of moisture from the gas), and increasing the conversion efficiency.

Materials Recovery Systems

Ferrous Metals

Ferrous recovery typically involved shredding, suspended type magnetic separation, air classification into light and heavy fractions, and pulley type magnetic separation of the heavies. Through the ferrous component is perhaps the easiest material to recover and has been widely demonstrated, two basic problems remain:

(1) ferrous losses in the light fraction resulting from air classification or from being physically bound with other waste materials, and
(2) impurities (primarily slag, tin, and copper) which make the recovered ferrous metals unacceptable to iron and steel scrap users.

Further work on improving the efficiency and reducing the cost of detinning is a promising area of research. Parallel efforts are called for in the redesign for aluminum recovery, of bimetal cans since the tops of these cans represent about one-third of the aluminum found in trash. An alternative approach is the development of a chemical method to remove the aluminum.

Research also remains to be done in the development of mechanized ways to identify copper in and to separate it from steel. Source segregation of steel scrap most likely to contain copper such as
white goods, and the Bureau of Mines’ concept of the use of light and heavy separation, are two methods in which work has been done.

**Aluminum**

Aluminum comprises between 0.5 and 1.0 percent by weight of municipal refuse, and has a high market value of 200 to 300 dollars per ton. Furthermore, a 95 percent energy savings is obtained by use of recovered aluminum scrap in production. The technology of aluminum recovery involved shredding, air classification, magnetic separation, and screening to yield a nonferrous concentrate from which aluminum is extracted by gravity separation, electric/magnetic field separation, or chemical/thermal separation. Several gravity and chemical methods are in small commercial use and also in minerals beneficiation. Aluminum magnets are also becoming commercially available (Combustion Power Company).

Aluminum scrap must generally be of high quality, since the presence of impurities such as stainless steel, zinc, magnesium and certain non-metallics (e.g., paint, oil, plastics, and rubber) decreases remelt efficiency and may lower the value of the scrap. The first full-scale aluminum recovery system, part of an energy recovery system, was installed in 1975 in Ames, Iowa.

Further research needs to be conducted in the following areas:

1. Aluminum magnets are a promising technology which need to be perfected, and extraction methods from other industries need further adaptation to process municipal and industrial wastes. These methods include heavy media (sink/float) separation, tabling, jiggling, sweating, froth flotation, and cryogenic separation.

2. Recovery techniques which do not involve shredding, and other novel approaches should be investigated.

3. Special attention should be given to the removal of impurities. The most troublesome of the commonly found metals are lead, tin, and bismuth, which segregate at grain boundaries during cooling and weaken the metal. The physical separation of different alloys and alloy types is a promising area for research.

4. Ways should be found to reduce losses of aluminum in recovery. The major losses occur in the air classifier (foil and can stock losses) and in the nonferrous metal recovery devices. One avenue worth exploring is alternatives to air classification and hydropulping for separation of organics from inorganics.

**Glass**

Glass cullet (high quality) now provides 10 to 15 percent of raw materials in glass container manufacture. Lower qualities of recovered glass can be used in glassphalt, glass brick, glass bead, slurry seal, foam glass, filler in plastics, glass wood insulation, wall panels, and tiles. Glass recovery technology is fairly well developed, although refinements and further developments should increase recovery yields.

Problem areas which require further research include:

1. Identification of the foreign materials in municipal and industrial waste that form stones under glass-making conditions. These stones adversely affect the stress properties of glassware, and can result in defective products.

2. Metal impurities also influence glass reuse. Copper, aluminum, and iron are particularly troublesome.

3. The causes of “seeds”, or tiny bubbles, need to be studied, along with ways to reduce the problem.

4. Characteristics of waste or glass recovery processes, which contribute to “cord” (i.e., a distinguishable second phase in the glass) are not well understood.

5. Further work is required in color sorting of glass to meet glass container manufacturing industry specifications and to determine its economic feasibility. Alternative and possibly novel methods for color sorting may have to be developed to do this economically. Conversely, careful investigation of the effects of lowering the industry specifications in certain cases, may prove to be quite valuable.

**CONCLUSION**

The field of resource recovery is rich in opportunities for research and development. This paper serves to highlight the most critical areas in need of R&D and presents some interesting topics for continued research in pre-processing and waste utilization. Since institutional issues will have a direct impact on whether or not a
particular process achieves widespread commercialization, research should also be conducted on providing incentives to the use of products recovered from waste.

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REFERENCES


ADDITIONAL REFERENCES


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