DOE/CS/20156-T1

AMERICAN PUBLIC WORKS ASSOCIATION

MASTER

THE RESOURCE RECOVERY OPTION IN SOLID-WASTE MANAGEMENT :

A REVIEW GUIDE FOR PUBLIC OFFICIALS

April, 1981

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

DISCLAIMER

This book was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

THE RESOURCE RECOVERY OPTION IN SOLID-WASTE MANAGEMENT

A REVIEW GUIDE FOR PUBLIC OFFICIALS

by

951 3523

American Public Works Association
1313 East 60th Street
Chicago, Illinois 60637

APWA Washington Office
1301 Pennsylvania Avenue, N.W.
Washington, D.C. 20004

Principal Author

Diane M. Nemeth ✓

Staff Associate - Energy and Environment
American Public Works Association

U.S. Department of Energy
Cooperative Agreement #DE-FC01-80CS20156

Project Officer
Donald K. Walter
Office of Energy from Municipal Waste
U.S. Department of Energy
Washington, D.C. 20585

TABLE OF CONTENTS

	Page
CHAPTER 1 - PROJECT MILESTONES	1
Lead Time	1
Legal Requirements	1
Financing	2
Permits	2
Procurement and Construction	3
Operation Start Up	5
 CHAPTER 2 - FINANCING	 7
General Obligation Bonds	7
Municipal/Special Revenue Bonds	7
Industrial Development Bonds	9
Leveraged Leasing	13
 CHAPTER 3 - RISK MANAGEMENT	 15
Waste Stream	15
Technology	16
Market	16
Environmental	16
 CHAPTER 4 - ENERGY AND MATERIALS RECOVERY	 18
Solid Fuels	18
Liquid Fuels	19
Gaseous Fuels	19
Electricity	19
Steam	20
Ferrous Metals	21
Glass	21
Aluminum	21
Paper	21
 CHAPTER 5 - MARKETING	 24
Market for Recoverables	24
Purchase Commitments	24
Federal Inducements	25

	Page
CHAPTER 6 - SELECTION OF A PROCESS SYSTEM	27
System Size	27
Nonprocessable Materials	29
Storage Requirements	30
CHAPTER 7 - OPERATION AND MAINTENANCE	32
Government	32
Special Authorities	33
Private Industry	33
CHAPTER 8 - SITING AND ENVIRONMENTAL CONSIDERATIONS	36
Site Selection	36
Environmental Effects	37

INTRODUCTION

The public works director is well aware of the problems encountered in disposing municipal refuse in a safe, environmentally sound, and cost-effective manner. Recent state and federal environmental regulations have rendered some of the more traditional methods of refuse disposal - such as incineration, ocean dumping, and landfilling - unacceptable.

Public works directors and local officials are looking at resource recovery systems as an alternate, environmentally acceptable method of disposing municipal refuse while recapturing valuable energy and material products.

Aside from the technical aspects of selecting hardware and system processes, there are a number of other important factors to consider before developing resource recovery systems. Unlike most other public works capital improvements, resource recovery systems contain an element of business venture and technical risk. Local governments contemplating development of resource recovery systems must learn to accept and manage the risks involved. Local governments operating resource recovery systems must also take on a new role of business entrepreneur. Producing a product for sale is an essential part of managing resource recovery systems. Securing market commitments prior to the facility's construction is crucial to the success of the project. Decisions must also be made about the type of system that is selected, its reliability and its capacity to meet the needs of the local jurisdiction.

The standard methods of procuring and financing local public works expenditures may not apply to resource recovery systems in a particular local jurisdiction and alternative methods may need to be examined. Even the commonplace methods of maintenance and operation by the public works department may no longer be valid with the implementation of waste-to-energy systems, and alternative operational and ownership arrangements may need to be considered. Endeavors to site resource recovery facilities may encounter citizen protest. Including a citizen participation element as well as considering all potential environmental impacts is very important to the site selection process.

All of these are important considerations that will affect the success of any resource recovery project. Being cognizant of them early in a project's development should lead to better decisions and reduce both the project lead time and completion period. It is the intent of this document to assist in that process by outlining the issues related to the implementation of resource recovery projects. The issues that are covered here include waste supply, markets, economic viability, siting, proven technology, financing, and environmental soundness.

This document does not address specific technologies or hardware processes. Descriptions of the technical aspects of resource recovery can be found in publications by the U.S. Environmental Protection Agency, the U.S. Department of Energy, the National Center for Resource Recovery and other publications listed in this paper's extended bibliography.

The purposes of this document, as perceived by the APWA Task Force on Energy, are to:

- * Serve as a guide for public works directors and others interested in implementing resource recovery systems
- * Provide background material which can be used in presenting information on resource recovery systems to city managers, mayors, legislative bodies and citizen advisory groups
- * Raise some issues of which local communities must be aware before developing resource recovery systems
- * Focus on possible institutional problems that may arise in planning waste-to-energy systems and present some solutions and alternatives
- * Serve public works officials as a reference for other publications on resource recovery systems
- * Aid public works officials in the decision-making process concerning the implementation of waste-to-energy systems

Members of the public works profession who are fully aware of all the implementation procedures involved with resource recovery systems can best decide if this is a feasible solid waste management option for their community.

CHAPTER 1

PROJECT MILESTONES

LEAD TIME

A lengthy amount of time is needed to plan and construct resource recovery facilities. Five or more years from the initial planning to the actual operation stage may be required. Thus, resource recovery facilities are not a short-term solution. Long-term commitments to the concept are required prior to initiating studies. Extensive efforts are needed to minimize time delays to avoid the increased cost of capital in periods of high inflation and rising interest rates. Myriad legal and environmental requirements must be successfully managed to obtain necessary permits. The actual construction and start-up phases may also be delayed due to problems with financing, equipment, procurement and the use of new technologies. Reduction of planning time in resource recovery development has been a high priority among supporting federal agencies including the U.S. Department of Energy's Office of Energy from Municipal Waste.

LEGAL REQUIREMENTS

Legal requirements affecting solid waste management vary from one jurisdiction to another and must be researched before a resource recovery program is implemented.

Federal, state and/or local laws regulate the permitting process, restrict the selection of sites, and forbid transporting refuse across state lines and establishing pricing structures by two or more participating jurisdictions. In some cases, unintentional barriers are written into the law and the law may need to be clarified or amended. In other cases, new laws may be needed.

As an example, the State of Maryland in 1980 established a Solid Waste Management Commission to examine a number of issues in regard to solid waste management, including jurisdictional impediments. To fulfill this charge, the commission compiled and analyzed sections of the Maryland Annotated Code and public local laws and made the following recommendations:¹

1. The law be clarified as to whether both the legislative and adjudicatory processes must be followed before a permit can be issued, as interpreted by the Department of Health & Mental Hygiene. If this interpretation is correct, the commission recommended that only a legislative hearing be required prior to action on a permit and that adjudicative action may follow issuance of a permit.
2. The permitting process be consolidated when more than one permit is required by different agencies.

3. The law be made sufficiently flexible to allow an applicant for a resource recovery plant to begin preparation for a site prior to the issuance of a permit or at least be able to consider a staged permit process. This recommendation was made in recognition of the risk involved by an applicant.

4. Enabling legislation be passed to permit two or more jurisdictions participating in regional solid waste management to be exempted from federal anti-trust provisions so that they may establish pricing structures.

5. Rescinding the law which forbids issuance of a permit within one-half mile of a hospital. This has been a significant barrier to local solid waste management in heavily populated areas which have many hospitals.

FINANCING

Acquiring capital to build resource recovery facilities may be a lengthy process. Long-term credit arrangements for multi-million dollar facilities are complex and may require months of negotiation with teams of financial analysts and bond counselors. For example, an eight-person staff was employed by the State of Connecticut to work along with an investment banker and general counsel for nearly a year to finalize a contract on a \$50 million resource recovery system.²

Some forms of financing, such as industrial revenue bonds, will require rulings by the U.S. Internal Revenue Service on a project's eligibility. The ruling process can be lengthy especially if the financing will include both tax-exempt debt and private capital.³

Delays in financial arrangements can increase the cost of projects due to inflation and increasing interest rates. For example, if financing complications delay a \$50 million purchase three months, the private sector's bid on the project's construction and operation may escalate. Assuming an average inflation rate of 1 percent per month, the capital costs of the facility will increase by \$1.5 million⁴

PERMITS

Obtaining necessary local and state permits can be a tedious process. First there is a question of definition: are resource recovery facilities to receive the same zoning and legal considerations as landfills, or are they to be treated as an industry? Stack-height restrictions, zoning requirements, and ordinances restricting waste disposal sites are but a few of the local and state requirements that must be observed with the proper steps taken for compliance.⁵

In a report compiled by the Mitre Corporation as background material for a 1978 symposium conducted on "Actions to Increase Resource Recovery Implementation," a diagram was included describing the permit process used for the Northeastern Massachusetts Resource Recovery Project. This flow-

chart has been reproduced with Mitre's permission to illustrate the complicated permit process involved in developing a resource recovery system (see Figure 1). Although each state and local jurisdiction will have different requirements, many of the restrictions will be similar. If a regional resource recovery system is constructed, it may be necessary to give the host community some financial incentives to compensate for complicated legal requirements and institutional obstacles that must be overcome.

PROCUREMENT AND CONSTRUCTION

Once an agency has decided to implement a resource recovery system, decisions must be made as to who will design, construct, operate and manage the facility. Inasmuch as resource recovery facilities generally require highly sophisticated technical and management skills, many communities may opt for a full service approach in which one firm will be selected to arrange financing, design, construct, and operate the facility. Special arrangements may have to be made to accommodate this method of procurement.

If a full service approach is taken by the agency, the typical municipal competitive bid system will not be followed and authorization must be secured to use a full service system. Informal or formal proposals will be compared and a firm selected. Negotiations between the firm and the public agency will take place before a contract is signed. Exemptions may need to be obtained from existing state or municipal law to allow non-competitive bidding and still protect the public interest. The length of full service contracts is often twenty years or more. Operation responsibility will lie with the firm that constructed and designed the facility. Many state laws presently prohibit municipalities from entering into long-term contracts. Municipalities may have to seek exemptions from the law or have the law changed. Obtaining legislative exemptions or changing state laws can be very time consuming and can delay the project for months. This places a premium on determining the procurement process, and possible impediments to it, at a very early date in the planning process.

The bidding system, either formal or informal, may also consume a great deal of time. Since there are no off-the-shelf formulas for resource recovery procurements, many of the documents that have been used are poorly designed, do not allow full comparison of proposals received, and do not meet the municipality's original objectives. As a consequence, the bid process has often been repeated.⁶ If the exercise is repeated, private firms may find the procedure too costly and withdraw from the competition or even the industry.⁷ Properly designed bids with a firm commitment to proceed with developments are vital for cost and time considerations. Once the procurement process has been completed and a contract has been signed, the construction phase should begin. Barring unusual construction problems, this phase may take from one to three years.

Figure 1

- ① Submit Preliminary Sub-Division Plan
- ② Planning Board and Public Meetings
- ③ Approval of Preliminary Sub-Division Plan
- ④ Prepare Construction Drawings
- ⑤ Prepare Definitive Sub-Division Plan
- ⑥ Submit Construction Drawing to Planning Board
- ⑦ Informal Submission of Drawings to Town Engineer
- ⑧ Submit Definitive Sub-Division Plan
- ⑨ Submit Plan to Electric Utility
- ⑩ Submit Plan to Gas Utility (if needed)
- ⑪ Town Review of Construction Drawings
- ⑫ Planning Board Public Hearing
- ⑬ Local Board of Health, Conditional Approval
- ⑭ Department of Public Utilities' Crossing Approval
- ⑮ Planning Board Approval Construction Drawings
- ⑯ Final Approval of Sub-Division Plan
- ⑰ File for Board of Health Permits/Variances
- ⑱ File for Zoning Permit to Board of Appeals
- ⑲ Sub-Division Appeal Period
- ⑳ Local Board of Health Final Approval
- ㉑ Environmental Assessment Form Filed
- ㉒ Qualified Approval by Board of Health
- ㉓ Hearing - Board of Appeals
- ㉔ Resubmit Linen Plan, Covenants and Documents
- ㉕ Prepare Environmental Impact Statement

- ㉖ Selection, Approval/Submit Water Pollution Control Formula
- ㉗ Board of Appeals Approval
- ㉘ Endorsement of Linen Plans
- ㉙ Informal Water Pollution Control Approval
- ㉚ Wetlands/Conservation Commission Determination of Applicability
- ㉛ Board of Appeal Decision
- ㉜ Recording of Sub-Division
- ㉝ Water Pollution Control Permit Issued
- ㉞ Revise/Distribute Construction Drawings
- ㉟ File Notice of Intent - Wetlands, Conservation Commission
- ㊱ Final Zoning Approval - Building Inspector
- ㊲ Public Works - Dike Approval
- ㊳ Planning Board Approval - Revised Drawings
- ㊴ Local Hearing - Wetlands
- ㊵ Furnish Bond to Planning Board
- ㊶ Curb Cut Approval - State
- ㊷ Board of Health - Issue Permits
- ㊸ Order of Conditions - Wetlands, Conservation Commission
- ㊹ Structural Review of Plans - Building Inspector
- ㊺ Approval Plan - Fire Detections
- ㊻ Historical District Plan Review
- ㊼ Appeal of Wetlands to D.E.Q.E.
- ㊽ Wetlands Hearing by D.E.Q.E.
- ㊾ Pay Fee and Issue Building Permit

Flow Chart of Permit Process for the Northeastern Massachusetts Resource Recovery Project

Source: Mitre Corporation (Metrek Division), Resource Recovery Implementation an Overview of Issues, October, 1978, p. 2-17.

OPERATION START-UP

Once construction has been completed for a resource recovery facility, there still may be a considerable time delay until the project is fully operational. Discovering operational problems or problems with equipment occurs during the shakedown period. Until problems are corrected, the plant cannot accept refuse on a continual basis nor meet its market commitments. The length of the shakedown period will depend upon how well the equipment and the facility functions. Since resource recovery technologies are still relatively new, shakedown periods may be quite lengthy.

Resource recovery technologies for the most part have been developed from other technologies which process materials and use fuels other than municipal solid waste. Refuse handling equipment, separation systems for recovering materials, and equipment used to produce shredded refuse derived fuel (RDF) originated with technologies used in the mineral dressing and the pulp and paper industries. Combustion units used in the last century to generate steam from coal have been the models for spreader-stoker combustion units developed to burn RDF as a primary fuel. Innovative procedures adapted to these older technologies to process refuse or use it as a fuel are not always successful.⁸

Municipal solid waste is not a homogeneous material. Particle size and shape, composition, moisture content, density, bulk, and chemical content vary throughout the waste stream. Refuse is difficult to process and can be a corrosive and even an explosive fuel. Extremely moist conditions, explosions or equipment jams may shut down a facility temporarily. Until a new facility is tested with its actual refuse supply, it will be difficult to determine if the processes will function smoothly or if there will be problems.

Pilot testing of resource recovery equipment and technologies does not always produce enough accurate feedback to develop full-scale systems. Resource recovery facilities have been known to have problems with materials handling and processing equipment. Specifically shredders, air classifiers, lack of adequate screening devices, and densification processes are the major concerns.⁹ Corrections need to be made in these and other processes to ensure the smooth functioning of the resource recovery system. Until all of the problems with the newly constructed resource recovery facility are cited and corrected in the shakedown period, the system cannot be fully operational.

FOOTNOTES TO CHAPTER 1

1. State of Maryland, Solid Waste Management Commission, Implementing Resource Recovery in the State of Maryland, 1981, p. 11.
2. U.S. Environmental Protection Agency, Resource Recovery Implementation: Financing (Washington, D.C., 1979), p.3.
3. Charlotte Rines and Peter Donnelly, "The Effect of Existing Law on the Financing of Municipally Sponsored Systems for Converting Municipal Waste to Energy," paper presented at a DOE-EPA sponsored workshop, "Utilities and Financing for Waste to Energy Projects" (Baltimore, Maryland, May, 1980), p. 2.
4. U.S. EPA, Financing, p. 3.
5. Mitre Corporation (Metrek Division), Resource Recovery Implementation: Overview of Issues (Oct., 1978), pp. 2-16 to 2-17.
6. Rines and Connolly, "The Effect of Existing Law on the Financing...", p. 3.
7. Dr. Harvey Alter, "Making Resource Recovery Economical," Phoenix Quarterly, XII (Fall 1980), p. 7.
8. Mitre, Resource Recovery Implementation, pp. 2-3 to 2-4.
9. American Association for the Advancement of Science, ed., Energy and Resource Recovery from Solid Waste, proceedings from a workshop of the Intergovernmental Science, Engineering and Technology Panel (Washington, D.C., 1979), pp. 194-200.

CHAPTER 2

FINANCING

Resource recovery facilities, often costing millions of dollars, will invariably necessitate some form of debt financing. Due to the uncertainties of resource recovery technologies and the business venture risks involved, few local governments are prepared to sponsor recovery facilities with the typical methods of bond financing.¹

The public works department, normally responsible for developing municipal solid waste management systems, may be unable to handle all the planning and financial arrangements for a resource recovery facility. Financial analysts and bond counselors are needed to arrange alternative methods of debt financing to obtain the greatest leverage with funds available. It is obviously important to choose investment counsel and underwriters familiar with resource recovery projects. Their experience and expertise can save both money and time.

The types of debt financing that may be utilized for resource recovery systems include general obligation bonds, special revenue bonds, industrial development bonds, and leveraged leasing.

GENERAL OBLIGATION BONDS (G.O.)

General obligation bonds are the least costly method of financing, since the interest on the bonds is both tax-exempt and relatively low.² The investor risk is also low since the full faith and credit of the issuing entity is pledged and an ad valorem tax is to be levied to make up any deficiency in the debt service. The ownership and operation of the plant is public. G.O. bonds are often viewed as the least desirable of all alternatives since the issuing entity must pay all expenses, including debt service, if the plant is not operable. Figure 2 illustrates the G.O. bond structure of the resource recovery facility operated by Ames, Iowa.

MUNICIPAL/SPECIAL REVENUE BONDS

Special revenue or municipal bonds are issued directly by a municipality, an authority, or quasi-public agency. These bonds are long-term and tax-exempt obligations issued as a security for a specific anticipated revenue stream. The flow of revenues from a resource recovery facility will be pledged as security for the bondholders. Revenues include waste disposal service charges, sales of scrap and other recovered materials, and possibly an operating contract with a private operator.

Figure 2

G.O. BONDS: AMES, IOWA

Source: Solid Waste Management Commission, "Solid Waste Management Commission Report for the State of Maryland", February, 1981.

The operation of the recovery facility can be either public or private. Since a city's taxing power does not support the project, the revenue bonds are not constrained by a city's current debt ceiling. Although the interest rates are higher than general obligation bonds, the interest rates are still within a moderate range.³

Municipal revenue bonds were used to fund the Nashville Thermal Transfer Corporation. Sixteen million dollars were raised to construct a resource recovery facility to sell steam to heat, and chilled water to cool, downtown Nashville buildings (see Figure 3).³ Special revenue bonding arrangements used in financing the North Little Rock, Arkansas modular water-walled incinerator are illustrated in Figure 4.

INDUSTRIAL DEVELOPMENT BONDS (IDB)

Industrial revenue bond financing may be the most widely used form of financing for resource recovery facilities. These bonds are issued by a municipality or a government entity to finance an industrial plant or equipment that will be leased or sold to a private corporation. The corporation's lease or sale payments must be sufficient to pay all of the costs of servicing the bonds.

The bonds are long-term and tax-exempt. The municipality only acts as a conduit through which the payments from the lease or sale flow from the corporation to the bond holders. The municipality is not responsible in the case of default since the municipality did not pledge its credit or taxing power to support the issue. The credit of the corporation which is leasing or buying the facility supports the industrial development bonds.⁵

The widespread use of IDB issues in the mid-1960s prompted a strain on the municipal bond market and legislation was passed in 1969 to curtail the use of these bonds with some exemptions. Section 103(b)(4) of the Internal Revenue Code lists seven categories of activities, including solid waste disposal facilities, for which governmental units may issue industrial revenue bonds. These bonds include tax-exempt interest even though the proceeds will be utilized by non-exempt persons. The IRS tax-exempt status supports the belief that solid waste disposal facilities are within the public interest even though operations may not be carried out by a governmental entity.

Though the interest rates on these obligations are higher than some of the previously discussed methods of financing, there are, however, substantial tax benefits. For the private corporation's equity participation, the following benefits are available: accelerated depreciation, investment tax credit, energy tax credit, and interest deduction.⁶

The resource recovery facility at Saugus, Massachusetts was financed through industrial development bonds and Figure 5 illustrates the Saugus bonding arrangement.

Figure 3

Source: Solid Waste Management Commission, "Solid Waste Management Commission Report for the State of Maryland", February, 1981.

Figure 4

SPECIAL REVENUE BONDS: NORTH LITTLE ROCK, AR.

--- CONTRACT FLOW
— CASH FLOW

Source: Solid Waste Management Commission, "Solid Waste Management Commission Report for the State of Maryland", February, 1981.

Figure 5

INDUSTRIAL DEV. BONDS: SAUGUS, MASS.

Source: Solid Waste Management Commission, "Solid Waste Management Commission Report for the State of Maryland," February, 1981.

LEVERAGED LEASING

In the future, leverage leasing may be an important tool in resource recovery financing. Leverage leasing allows a leasing company to obtain the use of an asset at a cost usually below its normal borrowing rate. The benefits to the lessor are usually greater than those available from long-term loans, revolving credit or more traditional financing mechanisms.⁷

When an equity investor puts up "risk" money for the project, he must find a debt investor to back the greatest portion of the loan (60 percent to 80 percent) in exchange for a good return commensurate with his security. The rate of the loan will usually be competitive with current bond or money market rates. The debt investor, usually a financial institution, obtains the mortgage on the full value of the asset and is given assignment of lease payments.

The financial arrangement is attractive to the equity investor since he is entitled to 100 percent of the tax benefits including accelerated depreciation, investment tax credits, energy tax credits and interest deductions. The equity investor needs only to maintain an equity of 20 percent of the leased asset. The lessee of the plant benefits since he can deduct lease payments as expenses and is not responsible for the debt obligation.⁸

Depending upon who issues the security, the income may or may not be tax-exempt. Often the issuer of the bond will be a corporation who will build and operate the plant under a long-term agreement. The tax benefits that are available bring the cost of the money down dramatically. Leverage leases are extremely complex and require a great deal of analysis in packaging the agreement.

FOOTNOTES TO CHAPTER 2

1. U.S. EPA, Resource Recovery Implementation: Financing (Washington, D.C., 1975), p. 3.
2. Solid Waste Management Commission, "Solid Waste Management Commission Report for the State of Maryland," March, 1981, p. 21.
3. Maryland Solid Waste Management Commission, "Commission Report," p. 21.
4. U.S. EPA, Financing, p. 8.
5. Discussion presented at a U.S. Department of Energy Workshop on "Utilities and Financing for Waste-to-Energy Projects," Baltimore, Maryland, May 5-7, 1980.
6. Maryland Solid Waste Management Commission, "Commission Report," p. 21.
7. Discussion from a DOE workshop entitled "Utilities and Financing for Waste-to-Energy Projects," Baltimore, Maryland, May 5-7, 1980.
8. Ibid.

CHAPTER 3

RISK MANAGEMENT

Risk management is new to many local governments. The inability of some to confront and manage risk may be one reason why so few U.S. resource recovery facilities have been built. Local governments are generally unaccustomed to evaluating technical and economic risks and would prefer in most instances to avoid them.¹ Municipalities are most familiar and most comfortable in purchasing proven public service equipment and facilities. When the risks associated with resource recovery are introduced, the decision making process becomes difficult for public administrators. The decisions become even more difficult for local politicians who must live with their choices at election time.²

The inability of communities to accept risk accounts for lengthy planning processes and explains why too few plants have been built. In Westchester County, New York, the planning process had been underway for over five years, and construction still has not begun as of December, 1980. Although bids for proposals had been received and a decision point was near, the legislative body hired a consultant to review the preparation work. When the consultant came to the same conclusion as the public administrator another consultant was hired to review the existing evaluation.³

WASTE STREAM

An assured quantity of refuse is necessary to produce the energy product. Problems may arise if jurisdictional control does not encompass the entire waste stream. The amount of waste generated per capita by a community rarely changes over the course of a decade. Changes in the supply of waste occur due to changes in population, competing methods of refuse disposal, the possibility of a refuse collection strike, and withdrawals by communities which no longer wish to participate in a regional resource recovery program.⁴ A common mistake made by the designers of early resource recovery facilities was to build extra capacity in anticipation of increases in refuse discarded per capita. The plant in Ames, Iowa was constructed to accommodate an increase in the waste supply and must operate today below capacity. Not only are there risks associated with the quantity of the waste stream over time, the quality of the waste stream is also questionable. This is an important consideration since the fraction of combustible material could decrease over time thereby decreasing revenues. If source separation is mandatory with paper and other recoverables not available, the heat value of the waste for resource recovery processes may be unacceptable. Changes in socio-economic factors and in packaging technologies could also alter the waste stream's composition.⁵

TECHNOLOGY

The technology-related risks involved with resource recovery facilities are twofold: (1) that the facility will not meet construction and operation schedules; and (2) that the technical processes involved may be inadequate to meet product demands and specifications.

There is also an obligation to the communities who have committed their waste to the facility. These communities must look for other means of disposal while waiting for the plant to begin operations. Auxiliary generating facilities to meet steam and electrical demands will eat into project revenues. Delayed delivery of energy and material products, or production of products that do not meet specifications, can result in the cancellation of purchase contracts.⁶

MARKET

The objective of resource recovery operations is to process waste and sell either energy, recovered materials, or fuel product. Hopefully the revenues earned from the sales along with disposal tipping fees will offset fixed and operating expenses. This equation will only be favorable if markets for the energy/materials products are secured.

It is important to secure a customer well in advance in the planning stages. The market's demand will dictate what type of resource recovery facility is built. Long-term purchase contracts will ensure needed revenues for operations. By seeking long-term contracts with product quality and composition specifications, design features can be built into the facility to produce the desired products.⁷

It is counterproductive to build a plant and then attempt to locate a buyer for energy/material products. The buyer may want alterations in the product which will lead to expensive changes in plant design and technology. If a buyer cannot be found or if buyers do not need the entire supply of products, the owners and operators of the plant will be left with a surplus of end-products and will not be able to meet their fixed and operating costs.

ENVIRONMENTAL

If environmental regulations change in the future, resource recovery facilities may require expensive pollution controls.⁸ It is therefore best to maintain a reserve fund to ensure that monies are available for plant and equipment changes if problems arise. There is also the possibility that hazardous wastes may be found in the waste stream. Explosive, radioactive, or chemically dangerous wastes could threaten the health and safety of the labor force. Removal of the hazardous wastes may shut down the facility indefinitely.⁹

FOOTNOTES TO CHAPTER 3

1. Dr. Harvey Alter, "Making Resource Recovery Economical," Phoenix Quarterly, XII (Fall 1980), pp. 6-9.
2. Susan J. Kinney, ed., Actions to Increase Resource Recovery Implementation (Symposium Proceedings, Oct. 1978), pp. 204-207.
3. Ibid.
4. U.S. EPA, Resource Recovery Plant Implementation: Risks and Contracts (Washington, D.C., 1979), p. 5.
5. Mitre Corporation (Metrek Division), Resource Recovery Implementation, pp. 4-6.
6. U.S. EPA, Risks and Contracts, pp. 8-9.
7. Alter, "Making Resource Recovery Economical," p. 8.
8. U.S. Congress, Office of Technology Assessment, Materials and Energy from Municipal Waste (Washington, D.C., 1979), p. 135.
9. U.S. EPA, Risks and Contracts, p. 9.
10. Mitre Corporation, An Overview of Issues, pp. 4-16.
11. Susan J. Kinney, "Overcoming Barriers to Resource Recovery," National Center for Resource Recovery Bulletin, (June 1979), p. 32.

CHAPTER 4

ENERGY AND MATERIALS RECOVERY

During the project's planning stage, market surveys will be conducted to determine potential customers and their energy requirements. Potential buyers of the energy and material products can then be contacted to ascertain their interest in the proposed project. Potential energy customers must be informed of the quantity and quality of the fuel or steam, its heat value, and reliability of supply. Before making purchase commitments, fuel users must determine the ability of existing boilers to accept the municipal solid waste (MSW) processed fuel or steam. Storage requirements for a buyer should be assessed as should needs for an auxiliary energy supply in case the plant is closed.

Once purchase commitments are secured, negotiations will be conducted with the buyer concerning price and product specifications. If design plans for the resource recovery facility accommodate the customers' product specifications, long-term purchase commitments should be secured from the fuel buyer.

Types of fuels available from MSW processes and their respective markets include: solid fuels, liquid fuels, gaseous fuels, steam, and electric power. The major materials that can be recovered and recycled from MSW are ferrous metals, aluminum, glass and paper.

Solid Fuels. Municipal solid waste can be separated into a light, combustible fraction of shredded or pulped refuse and a heavier non-combustible portion. The light fraction can be prepared as a fuel as a fine powder, light fluff, dewatered wet pulp, or as a densified pellet. The combustible fraction of MSW represents 70 to 80 percent of the total waste stream. Heat values range from 4500 to 6500 Btu per pound of refuse.¹

Refuse derived fuels (RDF) can be consumed in coal-fired electric power plants, industrial boilers, Portland Cement plants, and in new boilers or modified boilers designed to accept RDF exclusively.² RDF can be used as a supplement to coal, wood waste, bagasse, industrial waste, paper or agricultural waste, depending upon its particle size. The particle size should be small enough to permit complete combustion when burned in suspension. Residue content should be kept at a minimum to protect furnace walls and full firing systems. The ash content of RDF usually amounts to 20 percent. It is also important to keep moisture content at a minimum to maintain the heat value of the fuel.

Examples of RDF facilities include projects located in Ames, Iowa and Madison, Wisconsin.³

Liquid Fuels. The pyrolysis method of processing municipal solid waste can produce a liquid fuel used as a substitute for No. 6 fuel oil. The heating value of the pyrolysis liquid fuel is approximately 75 percent of the heating value of No. 6 fuel oil. The liquid fuel can also be used as a supplement with coal, wood waste, and other solid fuels.⁴

Large industrial or utility boilers can accept this fuel with modifications made to existing equipment for handling and storage requirements and to transfer the liquid fuel to the combustion zone. Extensive modification costs along with transportation costs may diminish the value of this fuel. Although there have been a number of pilot and full-scale liquid fuel pyrolysis plants that were constructed in the past decade, none is presently operational. Full commercialization of this process has not been successful to date.

Gaseous Fuels. The pyrolysis method of resource recovery can also produce a gaseous fuel with a heating value ranging between 100 to 500 Btu per cubic foot. This is a low heat content compared with natural gas which has a heating value of 1000 Btu per cubic foot. The pyrolysis gas cannot economically be stored or transported over distances of two to three miles. The inability to transport the gas over long distances will require location of facilities near customers. Due to large quantities of carbon monoxide found within the gas, its market is restricted to non-residential users.

Pyrolysis gaseous fuels with heating values above 300 Btu/cu ft (8.5 cubic meters) can be burned in any boiler or furnace equipped for natural gas, fuel oil, diesel oil, or solid fuel. If the gaseous fuel has a heating value below 300 Btu per cu ft (8.5 cubic meters), it cannot be transported and is best suited for on-site production of steam or electricity.⁵ To date, there are no pyrolysis plants producing gaseous waste-derived fuel in operation.⁶

Electricity. Resource recovery facilities producing steam can generate electricity on a plant site. Since electricity can be transmitted over long distances, it is highly marketable. Constraints to marketing will include the electricity's reliability, regulatory requirements, competing prices of electric power, and price setting considerations

There are a number of pricing problems with electricity generated by waste-to-energy facilities. The price of peak hour electricity is higher than base prices. Electricity from steam resource recovery plants is produced on a continuous basis. Therefore, peak and base load prices should be averaged to obtain the most accurate price for waste-derived electricity.⁷

Recent federal requirements under the Public Utility Regulatory Policies Act of 1978 (PURPA) have made the production of electricity by resource recovery facilities attractive. The act requires utilities to purchase power from co-generative and small power production facilities at

fair and equitable rates. Under PURPA small power producers, including resource recovery facilities, are assured of a market for their electricity output. By installing electric generating facilities on resource recovery plant sites, many market uncertainties will be eliminated. (See Chapter 5, page 25, for a further discussion of PURPA.)

Steam. Refuse burned in water-wall or modular incinerator units produces steam which can be used in space heating and cooling, process heating, and power producing applications. Markets for refuse-derived steam include district heating and cooling systems, industrial plants requiring steam on a continuous basis, and electric power plants.⁷

Resource recovery facilities usually produce steam at 600 pounds (272.7 kilograms) per square inch (psi) to minimize slagging and corrosion of boiler tubes. The steam can be processed further in separate units bringing it to required temperature and pressure. Since the steam cannot economically be stored or shipped over distances of two miles (3.2 km), location near customers is required. If the refuse-derived steam cannot meet the buyer's peak load capacities then stand-by, fossil-fuel burning boilers are necessary. Auxiliary fossil-fuel burning facilities will also be necessary due to plant shut-downs or stoppages in the delivery of the waste.⁸

District heating and cooling systems require steam at a pressure of 250 psi. Steam produced by resource recovery facilities can easily accommodate these systems. The steam requirement is usually constant throughout the day but may have seasonal variations. Since district heating systems usually support a central business district or industrial park, locating the facility near its customers should not be too difficult. If a district heating pipe network does not already exist, the construction costs may be prohibitive except in urban renewal areas or industrial parks. The steam produced by the recovery facility in Nashville, Tennessee is used to heat and cool a portion of downtown Nashville.

Industrial power plants that operate on a continuous basis, seven days a week, are preferred customers since water-walled incinerators are designed for round-the-clock operation. Industrial customers will specify needed quantities for delivery and required pressure. (The resource recovery facility in Saugus, Massachusetts pumps steam at 370,000 lb/hr @ psi/875 F to its neighboring customer, a General Electric plant.⁹)

A problem with steam electric power plants is the need to modify existing boilers to accept outside sources of steam. The modifications can be expensive and may require boiler shutdown while work is ongoing. These costs may be too prohibitive to consider the refuse-derived steam. A supplementary supply of steam may cause a boiler to operate at lower efficiencies, requiring additional amounts of fuel to reach the original output level.¹⁰ The resource recovery facility in Harrisburg, Pennsylvania has been pumping steam to the Pennsylvania Power and Light Company since 1972.¹¹

Ferrous Metals. Ferrous metals represent 8 percent of the municipal waste stream. Almost one half of all ferrous refuse is in the form of tin cans.¹² Ferrous metals are recovered from municipal solid waste in three methods. Tin cans may be sorted out through source separation collection programs. Front end separation processes magnetically remove ferrous metals in RDF or pyrolysis plants. Magnets are also used to remove ferrous metals from incinerator ash.

The three major markets for ferrous metals are tin recovery systems, copper precipitators, ferroalloy and steel remelt industries, and foundries producing gray and ductile iron. Each of these industries requires different processing techniques. Customer contracts are needed before installing separation equipment to meet product specifications. It may be most economical to extract the dirty ferrous and sell it to scrap dealers for processing. The cost of transporting and processing the recovered ferrous, considered along with possible revenues received, will influence the recovery decision.¹³

Glass. Glass can be recovered from the municipal solid waste stream through source separation programs as broken or non-broken glass, either color sorted or non-color sorted. Glass can be removed from the waste stream as "cullet," using optical sorting techniques or as "fines," through resource recovery froth flotation processes.

Recovered glass can be used to manufacture bottles if clean and free from refractory particles. Production of clear bottles requires color-sorted waste glass, while green or brown glass production does not demand color sorting. Bottle manufacturers have recently increased their interest in recovered glass. Waste glass uses less energy in production processes than virgin raw materials. Air pollution is reduced when using waste glass and allows industry to meet production emission standards. Experience has shown that the glass industry can use increased amounts of cullet without operational problems.¹⁴

Aluminum. Aluminum represents only about 0.7 percent of the municipal solid waste stream, and about one half of all aluminum discards are cans. The primary aluminum industry will purchase aluminum cans that have been separated from the waste stream through source separation programs. Recovered aluminum can be remelted and used in lower grade aluminum products such as castings. It is anticipated that the aluminum industry has the ability to absorb all acceptable recovered aluminum scrap.¹⁵

Paper. Paper products are recovered from the waste stream by source separation programs. Failing to separate waste at the source will render the waste paper unacceptable for reprocessing. In 1978 the American Paper Institute estimated that 24 percent of all paper and paper board products were recovered. Processors of paper and paper board products are the biggest market for recovered paper.

Commercial processes are presently being developed to produce newsprint from 100 percent recycled newspaper. If this process grows and continues to be successful, the presently highly volatile recycled paper market should stabilize.¹⁶ The competition between the use of waste paper for recycling purposes or as a high heat value fuel in resource recovery processes is continuing to grow. Opposition may exist to the development of new resource recovery facilities in those communities where private firms or environmental groups collect waste paper for recycling purposes.

FOOTNOTES TO CHAPTER 4

1. U.S. EPA, Resource Recovery Plant Implementation: Markets (Washington, D.C., 1979), p. 3.
2. U.S. Congress, Office of Technology Assessment (OTA), Materials and Energy from Municipal Waste (Washington, D.C., 1979), p. 51.
3. Ronald E. Schwegler, "Solid Waste Facts" from a paper presented at the 1979 International Public Works Congress and Equipment Show sponsored by the American Public Works Association in Portland, Oregon.
4. OTA, Materials and Energy, p. 52.
5. Ibid.
6. National Center for Resource Recovery, "Resource Recovery Roundup," Waste Age, XI, (Nov. 1980), pp. 54 to 62.
7. OTA, Materials and Energy, p. 52.
8. U.S. EPA, Markets, pp. 4 to 11.
9. Ronald E. Schwegler, "Solid Waste Facts."
10. U.S. EPA, Markets, pp. 4 to 11.
11. Ronald E. Schwegler, "Solid Waste Facts."
12. OTA, Materials and Energy, p. 52.
13. U.S. EPA, Markets, p. 14.
14. OTA, Materials and Energy, p. 48.
15. Ibid., pp. 48 to 49.
16. Ibid.
17. Ibid., pp. 49 to 50.

CHAPTER 5

MARKETING

MARKET FOR RECOVERABLES

Reusable materials can be recovered from the waste stream by source separation, front-end separation at the recovery plant, or by recovering materials from the processed residuals. Recovering non-combustible waste will provide a higher quality fuel in most cases. Recovered combustible wastes may decrease the heating value of the fuel.

Buyers for recovered materials should be secured before installing separation equipment at the recovery facility. Different markets for recovered materials may require different recovery methods. It may be more practical and economical to recover the materials at the recovery facility and sell it to scrap dealers for further processing. The location of markets and transportation costs will determine the feasibility of recovering materials.

The markets for recovered materials will vary due to supply and demand variations. Materials recovered from MSW must compete in the existing scrap materials market. Prices paid for recycled goods are tied to fluctuations in the business cycle. As business activity increases, the demand for recovered goods may also increase. Revenues from recovered materials will depend upon processing costs, transportation costs and prices paid.¹ The decision to recover materials may be based upon the economics involved.

PURCHASE COMMITMENTS

When negotiating over purchase specification, a contingent letter of intent to purchase or bid to purchase should be secured. (Publicly owned resource recovery facilities must give all responsible and responsive bidders an opportunity to purchase the recovered goods so a letter of intent to bid rather than purchase is necessary.) The letter of intent should include the length of commitment, the quantity of material to be purchased, the quality of the material, a delivery schedule, termination requirements and price. Price and discount schedules could be added to reduce the risks perceived by both buyer and seller of the energy and recovered materials.²

The most favorable marketing situation exists where a customer will approach a city requesting entire resource recovery energy output. This situation occurred in 1976 in Salem, Virginia when the local Mohawk Rubber Company requested the city to build a resource recovery steam producing plant. The company offered to purchase the entire steam output and to offer a site for the facility. Since Salem was experiencing a landfill shortage, the request was well received. The situation was mutually rewarding to both

the city and the company. The city's refuse disposal problem was alleviated, and Mohawk was assured of a fuel supply during a then existing natural gas shortage. This situation may become more common in the future in the event of fuel shortages.³

FEDERAL INDUCEMENTS

The federal government has encouraged the development of municipal solid waste as an alternative fuel both directly and indirectly through recent energy legislation. Both the Public Utility Regulatory Policy Act of 1978 and the Powerplant and Industrial Fuel Use Act of 1978 encourage the production of MSW as an alternative fuel.

Under the Public Utility Regulatory Policies Act of 1978 (PURPA) each state utility commission is required to enact a program compelling those utilities under their jurisdiction to purchase power from co-generation and small power production facilities. Under PURPA utilities must purchase power from the co-generation and small power production facilities at fair and equitable rates. Through PURPA co-generation and small power production facilities were exempt from state and federal utility regulation. For local communities with resource recovery facilities, implementation of the regulations will ensure a market for energy and outputs.

The Power Plant and Industrial Fuel Use Act of 1978 (PIFUA) was designed to reduce this nation's dependence on imported fuels as a primary energy source by using alternative fuels in new or existing utility power plants or in industrial production facilities which generate steam or electricity. Coal is perceived as the primary alternative fuel although fuels derived from solid waste are also encouraged. The act states that no new electric power plants can be built, except for certain exemptions, which do not have the capability for using coal or an alternative fuel. New power plants cannot use natural gas or petroleum as primary fuels under PIFUA and after January 1, 1990 natural gas is not to be used as the primary fuel in existing electrical power plants. If existing power plants are determined to use coal or an alternative fuel without substantial modification and reduction in the power plant's output, the secretary of energy may order the plant to use alternative fuels.

PIFUA provides a direct incentive to develop MSW as an alternative fuel for future use in new and existing power plants when natural gas and petroleum are restricted from use. As an indirect incentive, loans may be facilitated by the Department of Energy to equip with pollution abatement equipment existing power plants that switch to coal or alternative fuels, if funds for this equipment are not available elsewhere. Thus directly and indirectly PIFUA encourages the use of MSW as an alternative fuel.

FOOTNOTES TO CHAPTER 5

1. OTA, Materials and Energy, pp. 48-51.
2. Dr. Harvey Alter, "Making Resource Recovery Economical," Phoenix Quarterly, XII (Fall 1980).
3. Jane L. Hough, "Energy Recovery Systems Pays Off," National League of Cities Environmental Report, August 25, 1980, p. 1.

CHAPTER 6

SELECTION OF A PROCESS SYSTEM

In developing resource recovery facilities, there are a number of planning options which will influence the system's total energy output, design requirements and needed refuse supply. Selection of system size will determine needed refuse requirements and needed regional participants. The energy output and marketing strategy will also be a function of system size. The type of resource recovery technology chosen will determine the need for auxiliary power facilities and needed storage and landfill requirements. Selection of equipment and process features will impact the facility's reliability.

SYSTEM SIZE

To date U.S. resource recovery facilities have predominantly been constructed on a large scale basis to provide economies of scale. These facilities accommodate waste in the 1,000 to 3,000 tons per day (tpd) range and serve local agencies or groups of agencies in the 500,000 to 1,000,000 population range. A resource recovery facility which processes 1,000 tpd (907,180 kilo) of refuse and services an area of approximately 57,000 people can provide an energy product with a heat value of approximately 9 billion Btu per day.

Although economies of scale can be realized through large scale operations there is only a small range of communities which could support such large facilities. The U.S. census bureau in its 1975 Current Population Report listed less than 25 communities with populations of 500,000 or over.¹ (See Table 1.) To accommodate large recovery systems, regionalized service areas may be needed. Organizational and institutional problems with regional service areas along with siting the facility may be difficult.

Large scale facilities are expensive to build and finance. Construction time can be from 30 to 36 months. Downtimes are extremely important at large recovery systems inasmuch as shut downs reduce revenues and the facility's ability to meet debt obligations. Auxiliary facilities will be needed during down times to meet purchase contract demands.

Marketing efforts for large scale systems can also be difficult. The 1,000 tpd (907,180 kilo) facility example previously cited could supply power for a 37 megawatt power plant. Most power plants are much larger than 37 megawatts and would hesitate in purchasing such an insignificant supply of power. Industrial purchasers must be large enough to support the recovery facility's output. Other market considerations, including offices and residential complexes, are usually too small to consider singularly and must be grouped together to absorb the facility's total output.

Table 1

U.S. City Size, Population, and
Waste Production in 1975

City size range (thousands)	Number of cities	Population (million)	Average Population per city (thousands)	Average municipal solid waste per city (tons/day)
5-10	1,463	10.3	7.1	12
10-20	977	13.8	14.1	25
20-25	238	5.3	22.0	39
25-50	514	17.9	34.9	61
50-100	230	16.1	70.0	122
100-250	105	14.9	142.0	248
250-500	34	11.8	348.0	609
500-1,000	17	11.3	664.0	1,160
over 1,000	6	17.8	1,970.0	5,200

Source: U.S. Congress, Office of Technology Assessments, Materials and Energy from Municipal Waste, (Washington, D.C., 1979), p. 109.

With these problems in view, developing resource recovery systems on a smaller scale becomes attractive. Small modular incinerators with heat recovery capacities are being viewed favorably. Modular incinerators with afterburners were originally designed to reduce industrial, hospital, commercial, and residential apartment waste in an environmentally sound manner. By adding heat recovery equipment, modular incinerators can burn a municipality's waste while supplying energy to an industry. Such a system has both favorable environmental and community development implications.

Modular Combustion Units (MCUs) vary in size and can accommodate anywhere from 100 pounds (220.46 kilo) to 2 to 3 tons per hour. Communities in the 8,000 to 200,000 population range can best utilize these units. Based upon census reports, the largest number of communities in the U.S. are within this size range.² (See Table 1.) The energy market for MCUs is also much greater than large scale 1,000 tpd (907,180 kilo) resource recovery facilities. Small industrial boilers and MCUs would be a beneficial combination as well as universities and large hospital complexes. Since units are modular and relatively small, the MCU's customer may provide a site for the facility. The Mohawk Rubber plant which utilizes the energy output from Salem, Virginia's MCU provided the site for the recovery facility.

Since MCUs are modular, additional units can be added to accommodate increases in the waste stream supply. Modular systems are also flexible since four units of 25 tpd or three units of 33.5 tpd could service a 100 tpd refuse generating area. Down time can be reduced if a number of modular units are utilized. If one unit is shut down its waste could be processed by the other units until repairs are made. Modular Combustion Units are factory pre-fabricated and total construction time ranges from 12 to 18 months.

MCUs are cost competitive compared with other resource recovery facilities. When comparing the actual cost per ton of waste processed by resource facilities over the past decade, MCUs are competitive even though only small amounts of waste are processed.³ The economies of scale theory for resource recovery facilities may no longer be valid in light of the fact that many existing large scale facilities (including Quebec City, Saugus, Mass. and Harrisburg, Penn.) are operating at below design capacities.⁴ As the modular combustion industry expands in the future, MCUs may become more popular as a means of waste disposal and energy recovery.

NONPROCESSABLE MATERIAL

Implementation of a resource recovery system may extend the life of an existing landfill but will not totally eliminate the need for landfill space. That portion of refuse deposited at the resource recovery facility which is non-combustible and non-recoverable must be landfilled as well as non-recoverable residuals from the resource recovery process. Landfill space must also be available during periods of system failure. Occasionally there may be periods when the flow of incoming waste will be excessive (after refuse collection strikes or during periods of extreme seasonal variations) and landfill space will be needed to dispose of the overflow.

Recovered materials that cannot be sold due to market price fluctuations will also need to be landfilled if storage is unavailable.

The type of resource recovery process that is implemented will determine the amount of residue waste that must be landfilled. Water-walled incineration processes will produce a residue which is approximately ten percent the volume of the input waste and approximately 25 to 35 percent of the weight of the original waste.⁵ Water-wall residue consists of ash, glass, ferrous and non-ferrous metals and unburned organics. That portion of the residue which is not recoverable will be landfilled. In refuse-derived fuel processes approximately 15 to 20 percent of the incoming waste cannot be utilized as RDF.⁶ The recoverable portion of the non-combustible waste will be removed through front-end separation processes leaving the remaining portion to be landfilled. Through pyrolysis, heated solid wastes release gases and leave a carbon residue called char. The char along with a residue slag made up of ash and noncombustibles will be landfilled after recoverables are removed. The amount of char that is produced will vary depending upon reaction time, reactor temperature and pressure, refuse particle size and the presence of catalysts and auxiliary fuels.⁷

Ideally a landfill for the residues and unprocessed wastes would be located on the resource recovery plant site. If an on-site landfill is not possible it would be best to utilize a landfill near the plant to reduce transportation costs. When landfill transportation costs become excessive, the profit margin of the plant's operations may be adversely impacted.

STORAGE REQUIREMENTS

Some storage facilities are required on site for most methods of resource recovery. The refuse may need to be stored before it is processed and the processed refuse-derived fuel and recovered materials may require temporary storage before shipment to customers. Some temporary storage capacity may also be needed before the processed ash and residuals are landfilled.

During water-wall incinerator processing the refuse is dumped into storage pits by the collection vehicles. After incineration has occurred the non-combustible portion is removed and taken to a temporary storage pit before it is landfilled. When refuse is processed into fluff RDF, the waste is shredded and air-classified into combustible and non-combustible fractions. The combustible portion is processed into refuse-derived fuel and must be stored pending transport to the fuel user. The noncombustible fraction must also be stored until recoverable materials can be removed and sold and the nonrecoverable portion landfilled. In the pyrolysis method of resource recovery the collected refuse is taken to a storage area before it is pyrolyzed. The unrecoverable residue from the process is temporarily stored before it can be landfilled.⁸

Problems occur when the resource recovery facility is shut down and the incoming waste must be stored on the site until processing can be resumed. This situation must be considered in allocating storage space.

FOOTNOTES TO CHAPTER 6

1. U.S. Congress, Office of Technology Assessments, Materials and Energy from Municipal Waste (Washington, D.C., 1979), p. 108.
2. Robert Brickner and Brenda Harrison, "Smaller May be Better," Waste Age, XI (March 1980), pp. 28 to 36.
3. Ibid.
4. Ronald E. Schwegler, "Solid Waste Facts," presentation at the 1979 APWA International Congress Public Works and Equipment Show, Portland, Oregon, 1979.
5. U.S. EPA, Resource Recovery Plant Implementation: Technologies (Washington, D.C., 1979), p. 26.
6. Ibid., p. 26.
7. U.S. EPA, Technologies, pp. 41 to 42.
8. U.S. EPA, Resource Recovery Implementation: Technologies (Washington, D.C., 1979), pp. 26 to 62.

CHAPTER 7

OPERATION AND MAINTENANCE

Once the waste-to-energy facility has been constructed there are several possible operational choices. Local government, a public authority, or a private firm could be charged with running the facility. There are a number of advantages and disadvantages for each choice. Recently there has been much discussion generated over the role of private vs. public operation of highly technical and business sensitive resource recovery facilities.

GOVERNMENT

Local government may elect to operate the resource recovery facility. If a public agency had been responsible for refuse collection and disposal, transferring this responsibility onto a private concern may not be logical. The city leadership may believe that substandard disposal practices or possible plant shut downs may result if they lose control over the facility's operation. Operational contracts with private firms usually extend for the life of the facility. Few local governments will be willing to allow a private concern to make decisions over the disposal of their citizens' refuse for fifteen years or more.¹

The "tried and true tested" method of procuring municipal facilities has been to select an architectural-engineering (AE) firm to design the facility. Bids are then requested from contractors to build the facility. All contracts are awarded on a competitive basis. In fact many states prohibit local units of government from entering into contracts that have not been competitively bid. After the facility is built the local public agency will usually assume responsibility for its operation utilizing its standard employee hiring practices. Most often this approach is the initial "least cost" situation.

There are problems with this approach however. The AE firm is responsible for the facility's design, while the building contractor is liable only to construct the facility to design specifications. The city arranges financing for the project and assumes ownership. If the facility fails, the city must incur the financial obligation and political consequences. Very often municipal employees responsible for running the facility are not familiar with the extremely technical and sophisticated equipment nor with the business and marketing aspects of resource recovery operations. Lack of experience in these areas may impede the facility's operation.²

Madison, Wisconsin is an example of a local government which has successfully developed and is operating a refuse-derived fuel resource recovery facility. The city selected an AE firm to design the facility and requested bids for its construction. Since February, 1979 the city has operated the facility. Based on a survey conducted by Ronald Schwegler for

APWA's 1980 International Public Works Congress and Equipment Show, the Madison facility may be one of the most successful resource recovery facilities in this country today.

SPECIAL AUTHORITIES

It may be advantageous to create a public authority to develop and manage the recovery facility. An authority is a special government agency created to direct the operations of a particular governmental function. The organization of an authority is independent from other local agency departments and includes a governing body and staff to provide services.

An authority may be in a better position than local government per se to operate a resource recovery facility as a business enterprise. Normal constraints on hiring of experts, marketing of products and letting contracts or subcontracts may have been properly modified in the enabling legislation. Freedom from undue political pressures may also assist the authority in running the facility.

Legal and organizational problems may be mitigated through the creation of an authority. For example, authorities set up to operate waste-to-energy facilities might be authorized to float bonds for construction financing even though local governments might be prohibited from doing so. Authorities may also be the best vehicle for governing and financing regional resource recovery facilities with many participating communities³ In some states, such as Michigan, it may be difficult to establish new authorities for resource recovery operations. If a new authority cannot be created, an existing authority may have to be utilized which might not be sensitive to the needs and operations of resource recovery facilities. The one problem in creating authorities to take control of local government functions is that an authority, once operational, may not always be as responsive to the public as elected bodies.

To expedite resource recovery implementation a number of states are looking at ways to help local agencies overcome development problems. The Massachusetts Bureau of Solid Waste Disposal is assisting localities in project organization, vendor selection and energy marketing. The Arkansas Department of Energy has successfully assisted Arkansas communities to develop and implement modular combustion systems which sell steam to local industry. The Connecticut Resource Recovery Authority (CRRRA) was established to assist in the development of resource recovery systems in Connecticut.⁴

PRIVATE INDUSTRY

Another approach in operating resource recovery systems would give primary responsibility to private industry. It is possible that a private firm could take the initiative in assessing a community's waste problem, acquire a site, and arrange for the sale of recovered energy and materials. The industry would then approach the local agency for the needed waste delivery commitments. Project financing, construction and operation could all be conducted by the private firm. Few local governments will relinquish

all of their solid waste disposal responsibilities to private industry, however. A balance between public agencies and private industry is usually reached over control and decision making issues. However, local governments are becoming interested in giving private industry a greater role in developing and operating their resource recovery facilities.⁵

A private firm can often design, build and operate a waste recovery facility less expensively than the local agency. If a recovery facility is operated by the same firm who was also responsible for design and construction, the facility may have greater likelihood for success. The design team's experience gained through pilot tests would be extremely useful during start-up operations. Managers operating recovery facilities on a profit incentive tend to run facilities more efficiently. The private contractor would be responsible for product marketing.

If a local jurisdiction decides to let a contractor construct and operate the recovery facility, a full service contract will be executed. Under this arrangement the public agency bears only a fraction of the risks involved. Local agencies may have to pay a premium for their reduced risk, but any expenses due to operational or catastrophic problems will be borne by the contractor and not the government. In the event of system failure, the local agency would not be responsible for the debt. Full service contracts may also alleviate some legal problems with contract letting and contract negotiations.

The biggest disadvantage with a full service approach to resource recovery is the local agency's lack of control. Should the private contractor decide to close the recovery plant for an extended period, the public agency would still have a responsibility to dispose of refuse. The agency also relinquishes its ability to select the facility's design or equipment. The contractor could try to reduce initial capital and equipment costs by sacrificing operating costs. Since full service contracts run for at least fifteen to twenty years, the municipality would be penalized with higher tipping fees over the lifetime of the recovery facility. Under a full scale contract the local government cannot force the contractor to install current technology and equipment innovations to reduce operating costs and tipping fees.⁶

Even considering the problems involved with a full scale service contract this approach may still be the most advantageous. Assigning construction, financial and operational responsibilities to private industry would certainly be the least difficult option for local government. The lack of technical and operational expertise in this emerging field, coupled with the risk involved, makes full service contracts with private industry attractive.

FOOTNOTES TO CHAPTER 7

1. U.S. EPA, Resource Recovery Plant Implementation: Planning and Overview (Washington, D.C., 1979), pp. 17-23.
2. Mitre Corporation (Metrek Division), Resource Recovery Implementation: An Overview of Issues (Washington, D.C., Oct. 1978), pp. 1-8 to 1-9.
3. U.S. EPA, Planning and Overview, p. 17.
4. Gordian Associates, Inc., Overcoming Institutional Barriers to Solid Waste Utilization as an Energy Source (New York, N.Y., 1977), p. 216.
5. Mitre, An Overview of Issues, p. 1-7.
6. U.S. EPA, Planning and Overview, p. 23.

CHAPTER 8

SITING AND ENVIRONMENTAL CONSIDERATIONS

Obtaining a site and receiving an environmental clearance are as important steps to resource recovery development as financing. Objections to a site by local citizen groups could forestall construction of a facility indefinitely. Resource recovery facilities that do not meet environmental standards will need expensive modifications. Facilities emitting potentially hazardous substances could possibly be shut down.

SITE SELECTION

The type of resource recovery process that is chosen influences site selection. Since water-wall and small modular incinerators produce steam or hot water which must be piped to a market within 2 to 3 mile distances, the resource recovery facility should be located near the user. Recovered gas from pyrolysis facilities and methane extracted from landfills and anaerobic digestion facilities must also be piped to the user. And facilities producing a dry, solid or powdered refuse-derived fuel (RDF) need rail or highway transportation accesses to ensure that their product reaches its markets.

Delivery of refuse to a waste-to-energy facility is a key factor in the decision making process. If a number of communities are participants, a central location must be chosen for the site and transfer stations may be needed to reduce collection costs. Access to the site by major arteries and highways reduces travel time by collection vehicles, and well constructed access roads to the facility are needed as they will be used by heavy collection vehicles.

The site should be located in an area that will best mitigate potentially harmful environmental effects. Since resource recovery processes produce some pollutants, the site should not be located where prevailing climatic conditions would trap the pollutants and cause adverse environmental conditions. The site should be large enough to support the necessary equipment and structures and allow for the constant ingress and egress of collection vehicles. The most advantageous site would also include a landfill for disposal of ash and particulate matter from the resource recovery process or be located near a landfill.

Although a particular site might be ideal in terms of access roads and a central location to participating communities and markets, local property owners' protests may make it unacceptable. Increased traffic, noise, odors, wear and tear on access roads, possible decreased property values and the unpleasant connotations associated with solid waste are but a few of the complaints generally lodged against resource facilities. Although waste-to-

energy facilities should be less objectionable than landfills, few communities will welcome one within their boundaries. If a group of communities are participating in a regional resource recovery project, the host community will undoubtedly realize savings in refuse transporting costs but other incentives may be needed to persuade it to accept the resource recovery facility. Royalty per ton payments could be provided in lieu of taxes to compensate the host community for its losses.¹

ENVIRONMENTAL EFFECTS

As previously mentioned, there may be some adverse environmental impacts stemming from waste-to-energy projects. Air pollution is the primary environmental concern which may result in costly pollution controls or even the closing of plant operations. For example, a resource recovery facility constructed in Hempstead, New York was shut down shortly after construction when dioxins were found in the plant's emissions. State emission standards vary and existing state of the art control may not be adequate to meet the standards for some types of facilities.

Particulate emissions from burning solid waste in water-wall incinerators or with coal is one of the chief environmental concerns regarding the source recovery process.² Those from water-wall incinerators have been found to be about 1.24 grains per standard cubic meter compared to the U.S. Environmental Protection Agency (USEPA) standards of 0.08 grains per standard cubic meter. But appropriate air pollution control equipment should bring the emissions to within USEPA standards. Plastics burned with municipal solid waste (MSW) can combine with water to form hydrochloric acid, sometimes a detriment to health and a cause of corrosion. However, scrubbers can control hydrochloric acid. Levels of other air pollutants including sulfur dioxide, oxides of nitrogen, carbon monoxide, and hydrocarbons are not considered significant when MSW is burned.

When refuse-derived fuel (RDF) is co-fired with coal, the level of sulfur dioxide emissions is actually reduced per unit of electricity produced since RDF has a much lower sulfur content than coal. There is evidence of increased air emissions of heavy metals such as beryllium, copper, lead, cadmium, and mercury when RDF is burned with coal. Heavy demands will be made on air pollution control equipment when MSW is burned with coal inasmuch as refuse has a greater ash content than fossil fuels.

Air emissions from pyrolysis plants may contain particulate matter as well as hydrocarbons and such gases as hydrogen sulfide and nitrous oxides. Biological systems can produce air pollution from the incineration of digester filter cake residues. When methane digester gas is cleaned, air emissions may result. Dry process refuse-derived fuel plants do produce dust, odor, and noise, but with proper design these can be confined within the plant site.

Wastewater from resource recovery systems may contain the following characteristics, some of which require control: high temperature, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD),

hydrogen ion concentration (pH), alkalinity, hardness, total solids, phosphates, nitrates, chlorides, fluorides, heavy metals, odor and color. A potential source of wastewater pollution from the water-wall incineration process is ash slurry. The RDF/coal fired plants may emit increased levels of BOD, COD and total dissolved solids into the wastewater. It is not well known what the characteristics of wastewater from pyrolysis plants are but discharges may be high in BOD, COD, alcohols, phenols, and other organic compounds. Biological resource recovery processes require large quantities of water in the digester process. Wastewater pollution results when the digester wastewater is discharged.

Combustion ash, pyrolysis residues, and particulate matter recovered from air pollution devices are the solid wastes resulting from resource recovery processes. When landfilled these solid wastes can produce undesirable leachates. Fly ash particulate from water-walled incineration processes may contain trace elements such as cadmium, lead, beryllium, and mercury. Biological waste disposal processes discard a solid residue which may contain a bacteria that could present a harmful leachate if landfilled.

Workers in resource recovery facilities may be exposed to some hazardous working conditions. Workers can be exposed to bacterial, fungal, and virological pathogens found in the waste stream during the shredding, classifying, and transporting activities. For example, the bacterial count in the Ames, Iowa plant was found to be 100 times greater than normal non-recovery plant environments. There is no information available at this time, however, on the impact of these pathogens on the workers' health.

Dust particles in and around resource recovery facilities may also pose a problem. There is the fear that the wide range of materials in MSW such as asbestos, metal dusts, and toxic substances may be harmful. Studies conducted at the Ames, Iowa plant show that approximately one half of the dust on a particle count basis is composed of particles less than 4 microns in diameter. Dust particles of about 2 microns in diameter can be retained in the lungs and present health problems. The National Center for Resource Recovery has conducted studies which show that about 12 percent of the dust emitted during operation activities in resource recovery plants is found to be in the harmful respiratory range.³ Thus more safety measures are needed for worker protection.

Explosions and fires have been common in resource recovery processes. Combustible vapors from gasoline, oils, and other hydrocarbons are subject to heat and sparks within the shredding operations. Gunpowder, military ordinance, and dynamite also have been found in the waste stream on rare occasions and can cause explosions and fires. Secondary dust explosions can also occur by explosive materials found within the processing areas which house the shredders. Since it is difficult to predict explosions, it is difficult to prevent them.⁴ Shredders are designed to withstand minor explosions. Thus, the damage that usually occurs affects the peripheral equipment, such as ducts and conveyors.

A study conducted in 1976 by a private consultant for the Energy Research and Development Administration surveyed forty-five MSW shredding

plants. A total of 95 explosions were found to have occurred within 34 of the 45 plants surveyed. Only five of the explosions had damages of \$25,000 or greater. Explosions within resource recovery facilities can be controlled by manual or automated surveillance on input material, explosion venting, explosion suppression/extinguishing systems, and water spray or equipment isolation.⁵ Aside from the threat explosions present to resource recovery workers, there is also the possibility that an explosion will close the plant and curtail the flow of end products.

FOOTNOTES TO CHAPTER 8

1. The Mitre Corporation (Metrek Division), Resource Recovery Implementation: An Overview of Issues (McLean, Va., 1978), p. 5-5.
2. Office of Technology Assessment (OTA), Materials and Energy from Municipal Waste (Washington, D.C., 1979), pp. 102-105.
3. OTA, Materials and Energy, pp. 102-107.
4. American Association for the Advancement of Science, Energy and Resource Recovery from Solid Waste (Washington, D.C., 1979), p. 42.
5. OTA, Materials and Energy from Municipal Waste, pp. 106-107.

BIBLIOGRAPHY

- Alter, Harvey. "Making Resource Recovery Economical." Phoenix Quarterly, XII (Fall, 1980).
- American Association for the Advancement of Science, ed. Energy and Resource Recovery from Solid Waste. Washington, D.C.: American Association for the Advancement of Science, 1979.
- Brickner, Robert and Harrison, Brenda. "Smaller May be Better." Waste Age, II (March, 1980).
- Gordian Associates, Inc. Overcoming Institutional Barriers to Solid Waste Utilization as an Energy Source. Washington, D.C.: Government Printing Office, 1978.
- Hough, Jane L. "Energy Recovery System Pays Off." National League of Cities Environmental Report, (Aug., 1980).
- Kinney, Susan J. "Overcoming Barriers to Resource Recovery." National Center for Resource Recovery Bulletin, (June, 1979).
- Kinney, Susan J., ed. Actions to Increase Resource Recovery Implementation. McLean, Virginia: The Mitre Corporation, 1979.
- Mitre Corporation (Metrek Division). Resource Recovery Implementation: An Overview of Issues. McLean, Virginia: The Mitre Corporation, 1978.
- National Center for Resource Recovery. "Resource Recovery Roundup." Waste Age, XI (Nov. 1980).
- Rines, Charlotte and Donnelly, Peter. "The Effect of Existing Law on the Financing of Municipally Sponsored Systems for Converting Municipal Waste to Energy." Paper presented at U.S. Department of Energy sponsored workshop, "Utilities and Financing for Waste to Energy Projects," Baltimore, Maryland, May 5-7, 1980.
- Solid Waste Management Commission. "Solid Waste Management Commission Report for the State of Maryland," Baltimore, Maryland, 1980. (Xeroxed).
- Schwegler, Ronald E. "Solid Waste Facts." Paper presented at the 1979 International Public Works Congress and Equipment Show, sponsored by the American Public Works Association, Portland, Oregon, Sept., 1979.
- Untitled Paper presented at a U.S. Department of Energy Workshop, "Utilities and Financing for Waste-to-Energy Projects," Baltimore, Maryland, May 5-7, 1980.

- U.S. Congress, Office of Technology Assessment. Materials and Energy from Municipal Waste. Washington, D.C.: Government Printing Office, 1979.
- U.S. Environmental Protection Agency. Resource Recovery Plant Implementation: Financing. Washington, D.C.: Government Printing Office, 1975.
- U.S. Environmental Protection Agency. Resource Recovery Plant Implementation: Markets. Washington, D.C.: Government Printing Office, 1979.
- U.S. Environmental Protection Agency. Resource Recovery Plant Implementation: Planning and Overview. Washington, D.C.: Government Printing Office, 1976.
- U.S. Environmental Protection Agency. Resource Recovery Plant Implementation: Risks and Contracts. Washington, D.C.: Government Printing Office, 1979.
- U.S. Environmental Protection Agency. Resource Recovery Plant Implementation: Technologies. Washington, D.C.: Government Printing Office, 1976.

EXTENDED BIBLIOGRAPHY

- Abert, J.G. "Resource Recovery: Finding What Works By Research, Demonstration, Testing and Evaluation." Solid Wastes Management/RRJ (December 1977): 42-44+.
- Alter, Harvey. "A Cautious Look at Resource Recovery: Municipal Solid Waste Can Yield Valuable Materials and Energy, But the Technology to Exploit this Resource is Still Developing." American City and County (September 1978): 75-76.
- Alter, Harvey. "Pitfalls When Planning Resource Recovery." Waste Age (March 1976): 12-14+
- Alter, Harvey, and Dunn, J.J., Jr. Energy From Wastes: American and European Experiences. Washington, D.C.: National Center for Resource Recovery, Inc., 1978.
- Alter, Harvey, and Dunn, J.J., Jr. Solid Waste Conversion to Energy: Current European and U.S. Practice. New York: Marcel Dekker, 1980.
- Antunes, George E., and Halter, Gary. "The Politics of Resource Recovery, Energy Conservation, and Solid Waste Management." Administration and Society (May 1976): 55-78.
- Barnett, Thomas M., and Kole, Nina S. "Get Together For Resource Recovery: Four Groups of Neighboring Communities Have Combined in Four Different Organizational Structures, All With the Same Goal: Establishing More Efficient and Ecologically Sound Solid Waste Disposal Problems." American City and County (November 1980): 39-42.
- Barnett, Thomas M., and Price, James D. "Prospects for Resource Recovery With District Heating Systems." Public Utilities Fortnightly (August 16, 1979): 21-35.
- Barton, Allan F. M. Resource Recovery and Recycling. New York: John Wiley, 1979.
- Barton, Brown, Clyde, and Loguidice. Oneida County Resource Recovery Study for Oneida County and New York State Department of Environmental Conservation. East Syracuse, N.Y.: Galson and Galson, 1976.
- Beck, Alfred H. "Resource Recovery -- Promise and Problems." APWA Reporter (December 1976): 6, 21.
- Bottiger, R. T., and Price, E.B. Municipal Solid Waste and Energy Resource Recovery in Washington State: A Status Report. Olympia, WA: Documents Center, 1979.

- Cheremisinoff, P.N., and Morrese, Angelo C. Energy From Solid Wastes. New York: Marcel Dekker, 1976.
- Christiansen, Howard F. "Monroe County [N.Y.] Sells Its Garbage; But Marketing Resource Recovery is a Double-Barreled Task." American City and County (February 1980): 75-77.
- Conn, W. David. "Planning For Resource Recovery: Lessons From the California Experience." AIP Journal (April 1978): 200-228+.
- Frankiewicz, T. D., ed. Energy From Waste. Ann Arbor, MI: Ann Arbor Science, 1980.
- Gersham, H. W., and Barnett, T. M. "How to Buy Resource Recovery." American City and County (April 1979): 73-75.
- Godfrey, Kneeland A., Jr. "Recycling Refuse Into Energy." Civil Engineering (September 1976): 86-93.
- Gorton, Tom. "In Ames, Iowa, They're Taking the Waste Out of Garbage." Planning: The ASPO Magazine (January 1977): 14-18.
- Helmstetter, Arthur J. "Resource Recovery For the Small Community: What Are the Options?" Solid Wastes Management/RRJ (November 1978): 92-96.
- Holloway, Robert. "Ames [Iowa]: Problems and Progress Continue." American City and County (May 1978): 56-58.
- Hove, Merlin C. "Burning Refuse-Derived Fuel: Solid Waste Recovery Provides Supplemental Fuel for Ames, Iowa, Plant." Public Power (May-June 1976): 20-23.
- Johnson, Charles A. "Resource Recovery Decision-Makers Guide." Washington, D.C.: National Solid Waste Management Association, 1980.
- McEwen, Laurence B. A Nationwide Survey of Waste Reduction and Resource Recovery Activities. Washington, D.C.: U.S. Environmental Protection Agency, 1976.
- Minneapolis-St. Paul, Minnesota, Metropolitan Council of the Twin Cities Area. Policies for Resource Recovery Facilities -- Amendments to the Metropolitan Development Guide on Solid Waste Management. St. Paul, MN: Metropolitan Council of the Twin Cities Area, 1976.
- "New Survey Breaks Resource Recovery Facilities Into Four Groups." Solid Wastes Management/RRJ (November 1979): 77-83.
- "Resource Recovery: A Status Report." Solid Wastes Management/RRJ (April 1978): 8.

"Solid Wastes Fuel District Heating Comeback." APWA Reporter (September 1980): 8.

"Solid Waste Reduction To Provide City With Saleable Energy." Public Works (September 1977): 125-26+.

Stearns, R. P., and Woodyard, J. P. "Resource Recovery and the Need for Sanitary Landfills." Public Works (September 1977): 106-109.

Swinehart, G. A., and Sanders, W.A. "Waste-to-Energy: Applying the Technology In the Real World." Solid Wastes Management/RRJ (May 1979): 20-28+.

Tylutki, Beatrice S. "Resource Recovery in New Jersey -- Where We Are and Where We're Going." New Jersey Municipalities (December 1978): 6-7.

U.S. Environmental Protection Agency. Resource Recovery Management Model: Overview. Washington, D.C.: U.S. Environmental Protection Agency, 1979.

U.S. Environmental Protection Agency. The Resource Recovery Industry: A Survey of the Industry and Its Capacity. Washington, D.C.: Government Printing Office, 1976.

U.S. Environmental Protection Agency, Office of Water and Waste Management. Resource Recovery and Waste Reduction Activities -- A Nationwide Survey. Washington, D.C.: Government Printing Office, 1979.

U.S. Environmental Protection Agency, Resource Recovery Division. Contracting For Resource Recovery Systems: A Compendium of Insights and Experiences From Three Projects: Volume I (Draft Copy). Washington, D.C.: U.S. Environmental Protection Agency, 1975.

Vence, Thomas D., and Powers, Diana L. A three-part series providing a brief comparison of the major waste-to-energy systems now being marketed.

"Part I: Technological Comparison." Solid Wastes Management/RRJ (May 1980): 26-34+.

"Part II: Environmental Energy and Economic Factors." Solid Wastes Management/RRJ (June 1980): 38-44+.

"Part III: Implementation." Solid Wastes Management/RRJ (July 1980): 44-47+.

Vesilind, P.A., and Warner, D. "Cities Should First Consider the Various Resource Recovery Systems." Solid Wastes Management/RRJ (May 1978): 63-72+.

Vesilind, P.A., and Warner, D. "Resource Recovery: An Overview of the Field's Technology and Options." Solid Wastes Management/RRJ (April 1978): 96-114.