SECOND UNITED STATES-JAPAN GOVERNMENTAL CONFERENCE ON SOLID WASTE MANAGEMENT

September 24-25, 1974

Washington, D. C.

U.S.A.

U.S. ENVIRONMENTAL PROTECTION AGENCY

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XVI. Joint Communique

XVII. Press Release in Environmental News

Schedule of Travel

Arrived Montreal	Wed.	Sept 18	5:15 p.m.	by AC-749 stayed at Sheraton Mt. Royal Hotel
	Thurs.	" 19	in p.m.	Mr. Grey arrived and met delegation at hotel
	Fri.	" 20	all day	ISWA sessions
	Sat.	" 21	" "	ISWA sessions
	Sun.	" 22	" "	free time, visited Montreal
Departed Montreal	Mon.	" 23	9:15 a.m.	EA-173
Arrived Baltimore	"	" "	11:29 a.m.	Mr. Sussman met with transportation
	"	"	in p.m.	visited Baltimore demonstration project
Departed Baltimore	"	" "	late p.m.	by official car
Arrived Washington	"	" "	evening	stayed at Channel Inn Motel
	Tues.	" 24	all day	U.S.-Japan Conference
	Wed.	" 25	" "	" " "
Departed Washington	Thurs.	" 26	9:45 a.m.	TW-461
Arrived St. Louis	"	" "	10:41 a.m.	Mr. Holloway met with transportation stayed at Stouffer's Riverfront Inn
	"	" "	in p.m.	visited St. Louis demonstration project
Departed St. Louis	Fri.	" 27	8:00 a.m.	SO-321
Arrived Memphis	"	" "	8:48 a.m.	plane connection
Departed Memphis	"	" "	9:30 a.m.	SO-219

Arrived Orlando	Fri.	Sept 27	12:05 p.m.	Mr. James met with transportation stayed at Kahler Plaza Inn
	"	" "	in p.m.	visited high water table landfill
	Sat.	" 28	in a.m.	visited solid waste management facilities at Disney World
	"	" "	in p.m.	free time, visited Disney World
	Sun.	" 29	" "	free time
Departed Orlando	Mon.	" 30	8:05 a.m.	DL-1101
Arrived Atlanta	"	" "	9:13 a.m.	plane connection
Departed Atlanta	"	" "	10:33 a.m.	DL-823
Arrived San Francisco	"	" "	12:08 p.m.	transportation by car rental stayed at Sir Francis Drake Hotel
	"	" "	in p.m.	free time
	Tues.	Oct. 1	all day	visited Stefanelli operations and Mountain View landfill
	Wed.	" 2	" "	free time
Departed San Francisco	Thurs.	" 3	12:30 p.m.	PA-001

II

PROGRAM

SECOND U.S.-JAPAN CONFERENCE ON SOLID WASTE MANAGEMENT

THEME: Optimization of Solid Waste Management Services

Tuesday, September 24

9:00-9:10 a.m.

Opening of Conference, Mr. Hickman, Chairman
Welcoming Remarks, Mr. Green

9:10-9:15

Welcoming Remarks, Mr. Strelow

9:15-9:20

Welcoming Remarks, Mr. Darnay

9:20-9:25

Introduction to the Conference, Conference Chairman, Mr. Hickman

9:25-9:30

Introduction to the Conference, Chairman of the Japanese Delegation, Mr. Fukuda

9:30-9:45

General Comments by APWA Representative, Mr. Fleming

9:45-10:00

General Comments by NSWMA Representative, Mr. Wingerter

10:00-10:15

Status of Solid Waste Management in the United States; Summary, Mr. Hickman

U.S. Paper: The Federal Solid Waste Management Program; Review and Prognosis, by H. Lanier Hickman

10:15-10:45

General Discussion of U.S. Paper

10:45-11:00

Coffee Break

11:00-11:15

Status of Solid Waste Management in Japan; Summary Mr. Fukuda

Japanese Paper: Present Condition of Solid Waste Management, by Tsutomu Fukuda and Tadayuki Morishita

11:15-11:45

General Discussion of Japanese Paper

11:45-11:50

Administrative Matters, Conference Chairman

11:50-1:30 p.m.

Luncheon: Hosts, NSWMA. Pier 7 Restaurant, Channel Inn

1:30-1:45

Collection and Transportation of Wastes in the United States; Summary, Mr. Colonna

U.S. Paper: Decision-Makers' Guide in Solid Waste Management, Chapters on Collection and Transportation

1:45-2:45

General Discussion of U.S. Paper

2:45-3:00

Coffee Break

3:00-3:15

Collection and Transportation of Wastes in Japan; Summary Mr. Nakano

Japanese Paper: Collection and Transportation of Household Solid Wastes, by Mitsuo Nakano

3:15-4:15

General Discussion of Japanese Paper

4:15-4:30

Closing Comments for the Day, Conference Chairman

About 4:30 p.m.

Adjournment

7:00-8:30

Reception for Japanese Delegation at Home of Mr. and Mrs. Hickman

Transportation for Delegation provided by EPA

Wednesday, September 25

9:00 a.m.

Open Second-day Session

9:00-9:15

Disposal of Wastes in the United States; Summary, Mr. Garland

U.S. Paper: Decision-Makers' Guide in Solid Waste Management, Chapters on Processing and Disposal

9:15-10:00

General Discussion of U.S. Paper

10:00-10:15

Disposal of Wastes in Japan; Summary, Mr. Miyanohara

Japanese Paper: Actual Conditions in Refuse Management in Japanese Cities and Treatment of Leachate and Gases Discharged from Landfill, by Takashi Miyanohara

11:00-11:15

Coffee Break

11:15-11:30

Hazardous Waste Management in the United States; Summary, Mr. Sanjour

U.S. Paper: Hazardous Waste Management in the United States, by Mr. Sanjour

11:30-12:15 p.m.

General Discussion of U.S. Paper

12:15-1:30

Luncheon: Hosts, Japanese Embassy, Flagship Restaurant

1:30-1:45

Hazardous Waste Management in Japan; Summary, Mr. Fududa/ Mr. Morishita

Japanese Paper: Treatment of Toxic Wastes, by Tsutomu Fukuda and Tadayuki Morishita

1:45-2:30

General Discussion of Japanese Paper

2:30-2:45

Resource Recovery in the United States; Summary, Mr. Humber

2:30-2:45

U.S. Papers:

Resource Recovery in the United States, by J. Nicholas Humber

Energy Conservation Through Improved Solid Waste Management, by Robert A. Lowe

Markets and Technology for Recovery of Energy from Solid Waste, by Steven J. Levy

Solid-Waste-as-Fuel Systems

Solid Waste Pyrolysis Systems

Pyrolysis of Municipal Solid Waste, by Steven J. Levy

2:45-3:30

General Discussions of U.S. Papers

3:30-3:45

Coffee Break

3:45-4:00

Resource Recovery in Japan; Summary, Mr. Nakajiku

Japanese Paper: Resource Recovery from Municipal Solid Waste in Japan, by Michio Nakajiku and Sukehiro Gotoh

4:00-4:45

General Discussion of Japanese Paper

4:45-5:00

Closing Statements of Conference Chairman, and Chairman of the Japanese Delegation

Issuance of Joint Statement

Conference Adjournment

CONFERENCE PARTICIPANTS

Japan

Mr. Tsutomu Fukuda (Chairman of Delegation)
Director, Water Supply and Environment Department
Ministry of Health and Welfare

Mr. Tadayuki Morishita
Head, Office for Industrial Wastes Management
Water Supply and Environment Department
Ministry of Health and Welfare

Mr. Michio Nakajiku
Project Manager, Office of Research and
Development Programs
Agency of Industrial Science and Technology
Ministry of International Trade and Industry

Mr. Mitsuo Nakano
Head, Urban Road Division
City Bureau
Ministry of Construction

Mr. Takashi Miyanohara
Assistant Division Director, Environmental
Cleaning Bureau
Yokohama City

Mr. Katsuhiko Suetsugu (Observer)
Business Correspondent, Industrial News Department
Editorial Bureau
Nippon Keizai Shinbun Co.

United States

H. Lanier Hickman (Conference Chairman)
Director of Operations for Solid Waste
Management Programs
U.S. Environmental Protection Agency

Fitzhugh Green
Associate Administrator for International Activities
U.S. Environmental Protection Agency

Roger Strelow
Assistant Administrator for Air and Waste Management
U.S. Environmental Protection Agency

Arsen J. Darnay
Deputy Assistant Administrator for Solid Waste
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J. Nicholas Humber
Director, Resource Recovery Division
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U.S. Environmental Protection Agency

Rodney F. Fleming
Executive Secretary, Institute for Solid Wastes
American Public Works Association (APWA)

Eugene Wingerter
Executive Director
National Solid Waste Management Association (NSWMA)

Escorting Personnel on Field Tour

Valentine Grey (escort)
Senior Staff Officer
Office of Solid Waste Management Programs
U.S. Environmental Protection Agency

David Sussman
Project Officer, Baltimore Demonstration Project
Resource Recovery Division
Office of Solid Waste Management Programs
U.S. Environmental Protection Agency

J. Robert Holloway
Project Officer, St. Louis Demonstration Project
Resource Recovery Division
Office of Solid Waste Management Programs
U.S. Environmental Protection Agency

Stephen C. James
Project Officer, Orange County Demonstration Project
Systems Management Division
Office of Solid Waste Management Programs
U.S. Environmental Protection Agency

INTRODUCTORY COMMENTS

H. Lanier Hickman, Jr.

It is a great pleasure for our country and Agency to host our solid waste management colleagues from Japan. We only hope that our hospitality can match yours when we were your guests in 1973.

We think it is significant that in the midst of the many energy and materials problems that face the world, that our two countries can meet to discuss solid waste management. It is significant because solid waste management can be and in many instances is a factor which can provide help in alleviating our energy and materials needs.

We want this meeting to provide an open exchange of knowledge and experiences. It should help us to better relate our important national and internationcal roles in the world's economy. Our experience tells us that professionals working in a particular field can achieve measurable results working together regardless of language and cultural differences. We know that this conference will achieve measurable results.

We look forward to this conference establishing a foundation for greater future cooperation between our two countries.

VI

THE FEDERAL SOLID WASTE MANAGEMENT PROGRAM
A REVIEW AND PROGNOSIS

by H. Lanier Hickman, Jr.*

The responsibilities and authorities for solid waste management in the United States are divided among the three formal levels of government: Federal, State, and local (county or city). Each level has discrete as well as shared activities.

The base of legal authorities in the U.S.A. stems from the Constitution of the United States, which provides for certain governmental functions to be provided by each level of government. Domestic Federal Governmental functions are based on the concept of interstate relationships, i.e., activities which cross State boundaries. State government functions pertain to all those aspects of governmental services within their boundaries, and individual State constitutions divide responsibilities between State and local government. These responsibilities actually restrict what each level of government does, thereby protecting individual rights and interests.

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*Mr. Hickman is Director of Operations for Solid Waste Management Programs, U.S. Environmental Protection Agency.

Federal Responsibilities

Present Federal Government authority in solid waste management is provided by the Solid Waste Disposal Act (Public Law 91-512)[1], as amended. This law was originally passed by the Federal Congress in October 1965, amended in October 1970 and extended in 1973. It will expire the end of June 1974 and will need amending or extending by that time. In the initial sections of the law, the responsibility of government is reviewed. Simply stated, the Act defines the responsibility of local and State government to be that of collection and disposal of solid waste. It further states, however, that the nature and dimensions of the solid waste problem in the United States require Federal action, in order to make possible the practices of proper and economical solid waste management by State and local governments. The Federal solid waste programs activities, as defined by the Act, are briefly described below:

Policy Formulation. The interactions and direction of solid waste management must be articulated to the Nation so that government, industry, and individual citizens will support the actions necessary to provide both effective and economical solid waste management and protection of the environment.

Research and Development. The development of new and improved techniques for solid waste management requires government action, not commonly associated with local/State government. Research and development is a logical function of Federal Government because of national needs and the costs of research.

Demonstration. The demonstration of new emerging technology and systems is both expensive and unpredictable. As with research, the breadth of national needs and high costs almost dictate that the Federal Government support this activity.

Technical Assistance. The provision of highly skilled technical expertise to assist local government and industry in dealing with their solid waste problems has long been a traditional role of Federal Government. This activity provides manpower to supplement State government technical assistance activities, to improve current systems, and to place new systems in operation.

Planning Solid Waste Management Systems. The original Solid Waste Disposal Act authorized Federal grants to State governments to help them develop long-range plans for their States. This authority provided a mechanisms by which the Federal Government could assist the State government in the formulation of strategies to meet their responsibilities as described by the Act.

Training. The existing Act provides the Federal Government with authority to train solid waste personnel in State and local government and private industry directly, to help universities establish college curricula on solid waste management, and to determine the national manpower needs of solid waste management.

State-of-the-Art Studies. When the Federal Government first began to exercise initiatives in solid waste management, information on solid waste technology was indeed sparse. If solid waste management systems are to meet their objectives, knowledge regarding acceptable technology, systems, and approaches must be provided. To provide such material, the existing Act authorizes studies to be made of existing technology to define in qualitative, quantitative, and comparative terms the application and acceptability of that technology.

Public Information. Only an informed technical and lay public is capable of making wise decisions on issues that affect the well-being of the individual, the government, and the Nation. Existing authorities allow for the expending of funds to inform the American public about solid waste management[2].

State Responsibilities

The activities of State government parallel those of the Federal Government in many areas. State government has better opportunities than the Federal Government to interrelate with local governments and people because of the proximity of State government and their perception of local problems. Nothing prevents State government from executing a program corresponding to all areas of the Federal solid waste management programs except the limitations of economics and practicality, but because of these limitations, little State effort has been directed to research and development, state-of-the-art studies and the demonstration of new and improved technology. In the areas of policy formulation, technical assistance, planning, training, and public information, however, State solid waste activities are very similar to Federal activities, except that the scope is directed at State/local problems and that these activities tend to be more detailed and specific to those problems.

The most important and demanding role of State government, and one that does not now rest with the Federal Government, is the establishment and subsequent enforcement of solid waste standards. Presently, within their constitutional authorities, State governments are responsible for the quality of operations of solid waste management systems within

their respective States.[3] Most states presently have legal authorities to enforce solid waste standards. A significant number of States base these authorities on old and limited laws governing nuisances and health. However, some 15 States have recently enacted solid waste legislation that broadens and strengthens the role of State government, particularly in relation to standard-setting and enforcement.

Local Responsibilities

Local government sees that solid waste is properly managed from storage--through processing and recovery--to final disposal. At the local level, solid waste is generated from residences, commercial enterprises, and industrial activities. The collection, treatment, and disposal of these wastes are accomplished by both governmental forces and private contractors.[4,5] Industries frequently manage their own solid waste which result from process lines, but have their general plant-type waste collected and disposed of by private or public forces. By far the greater part of industrial and commercial solid wastes are collected by private contractors. The majority of processing and disposal facilities are owned and operated by local government agencies, cities and counties. All of these operations must meet State standards and require technology and systems to serve their citizens.

The Federal Solid Waste Management Programs--1966-1970

As has been reviewed earlier, the original Federal legislation in solid waste management was the Solid Waste Disposal Act of 1965, subsequently amended by the Resource Recovery Act of 1970.[1] It seems logical to review the progress made by the Federal program and the nation in a way compatable with the legislative history, i.e., 1966-1970; 1971-1973; 1974 and the future. Except for 1965 and 1973, the funding for the Federal program has averaged about $14.3 million per year (Table 1).

Table 1

FEDERAL SOLID WASTE PROGRAM BUDGET

1966-1974

(By Fiscal Year)

($\times 1000^{\$}$)

	1966	1967	1968	1969	1970	1971	1972	1973	1974
Demonstration Grants	2,000	5,000	4,700	5,100	4,600	3,700	1,000	27,000	
Planning Grants	400	1,000	1,500	1,900	1,500	1,300	2,700	3,700	
Training Grants	150	350	450	500	400	1,000	250	1,300	
Research Grants	850	1,700	2,300	2,400	2,000	1,700	2,000	450	
Direct Operations (including contracts)	920	4,200	4,400	5,200	6,800	10,200	8,000	11,400	
	4,320	12,250	13,350	15,100	15,300	17,900	13,950	43,850	14,800

At the beginning of the program, major emphasis was placed on learning as much as possible about the practice and technology of solid waste mangement throughout the U.S., and on assisting States through the State planning grant program. The funds expended for State solid waste agency support from fiscal years 1966 through 1973 totalled over $10 million to aid 49 states in developing plans which establish long-term solid waste management strategies for State government (Table 2).

Table 2

STATE SOLID WASTE PLANNING GRANT EXPENDITURES

	FY 66	FY 67	FY 68	FY 69	FY 70	FY 71	FY 72	FY 73	TOTAL
Number of States Supported	14	31	36	35	31	32	32	34	49
Total Federal Funds by Year (000)	500	.1000	1,300	1,600	1,400	1,200	1,200	2,000	10,200

Most of the States have completed their plans and all, whether through the planning phase or not, are in some stage of implementation.

In determining the condition of solid waste management in the U.S., two surveys were conducted--one of municipally-owned operations, and one related to privately-owned operations.

Many research and demonstration projects were initiated and many were completed. All were not successful from the standpoint of being able to apply what was learned, but the fact that some projects proved that the concepts were not practical is, in itself, a useful contribution to the field. During the years 1966 to 1970, some $21 million was invested in demonstrating new or improved approaches and technologies for solid waste management.

Notable successes include the advancement of improved rural solid waste collection systems and technology[6]; the implementation of a true regional solid waste authority[7]; and the advancement of shredding of solid waste as a viable unit operation.[8] Many more have been reported on and the reports are available from our Agency the U.S. Environmental Protection Agency.[2,9] In fact, from the period 1966 through 1970, 450 publications were produced by the Federal solid waste program in order to make available the results of the Federal program.

One of the major areas of activity that resulted in significant and important outputs was the investigative effort leading up to the state-of-the-art reports on sanitary

landfill and municipal incineration. These two documents represent the most complete and authoritative reference sources on these two areas of solid waste technology available today.[10, 11]

From much of the 1966 to 1970 effort we were able to develop insights into the status of municipal solid waste management in the U.S. We were able to estimate the annual U.S. generation of solid waste at over 4 billion tons. We learned that the majority of these wastes came from agricultural and mining activities, but the 5 or 6 percent coming from municipal (urban) living (over 150 million plus tons) represented that segment creating the greatest environmental resource use concerns in the country. We learned where this 6 percent was being treated and disposed of in dumps, incinerators, and sanitary landfills, that an immeasurable portion was being recycled with the vast majority (75%) being disposed of on the land in an unacceptable manner. Almost 10 percent of the municipal waste stream went to incinerators, 75 percent of which was not capable of meeting existing air pollution standards. Collection, utilizing over 300,000 people and 90,000 pieces of equipment, while well ahead of treatment and disposal in sophistication and service, is still not up to a level that could be considered totally adequate. Almost 25 percent of the population received only partial

services or limited and inadequate service. Finally, we were able to determine that costs to individual cities and citizens for this inadequate national municipal solid waste management systems exceeded in the aggregate some $4.5 billion. Figure 1 summarizes these findings in some detail and is provided as an overview of the status of solid waste management in the U.S. at the end of 1970.

The Federal Solid Waste Management Program--1971-1973

The learning process of 1966-1970 served as a foundation to develop staff, begin state programs, and chart the directions for the nation in solid waste management. Also, a new piece of Federal solid waste legislation was enacted in October 1970--The Resource Recovery Act of 1970.[1] The amended Act came at the same time that the new Environmental Protection Agency (EPA) was established in the Federal Government. The Federal Solid Waste Program became part of EPA as the Office of Solid Waste Management Programs (OSWMP).

This Act, while still authorizing a continuation of past work, also authorized several new significant activities and studies: (1) the establishment of guidelines; (2) hazardous wastes; (3) resource recovery; (4) solid waste management manpower.

Guidelines. The guidelines efforts mandated by the Act were a natural extension of the state-of-the-art work begun in 1966. The guidelines developed will, in effect, be mandatory standards for Federal government solid waste management operations and will be a strong guide for State agency standard setting. Naturally, the first two guidelines developed were for sanitary landfill and incineration, both based on the aforementioned state-of-the-art reports.[12]

Hazardous Wastes. The Resource Recovery Act also required that the Federal solid waste program initiate a detailed study of hazardous waste management in the U.S. and provide a report to the Congress of the United States. The report was formally submitted to Congress in the fall of 1973.[13]

The major findings of that report indicated that the amount of hazardous waste generated in the U.S. was 10 million tons annually and growing at a 5 to 10% annual rate; that our current management practices were unacceptable; that because of increasing air and water pollution regulations, more and more of these hazardous wastes were going on the land and the regulations (Federal, State and local) to protect the land were inadequate and usually non-existent; there was little pressure on generators to do a good job of disposal; that technology, while available for many wastes, was not utilized;

and that a combination of Federal and State action was necessary to regulate these waste materials to assure proper management.

Resource Recovery. The most far-ranging change in the amended Solid Waste Disposal Act related to resource recovery. Because of the long-term impacts of material usage patterns, initiatives by the Federal government into resource recovery areas moves remarkably away from the rather routine purposes of today's solid waste management system. Congress directed the Federal solid waste management program to study and determine ways to recover materials and energy from solid waste; ways to reduce the amount of solid waste; analyze changes in solid waste management systems to bring about increased resource recovery; determine how to use Federal procurement to stimulate resource recovery; assess the impact of current taxing procedures on the utilization of secondary materials; and analyze how public policies affect and can affect resource recovery.

The Federal solid waste management program is required to report on the findings of these studies annually. The first report was submitted to the Congress in October 1972.[14] The emphasis of the first resource recovery report is on the recovery of materials and energy from mixed municipal wastes and other "post-consumer" wastes that are discarded outside

the normal waste collection channels. The report indicates that although only 5% of the total national solid waste load, post-consumer wastes tend to have the most frequent population impact in that they occur in the nation's urbanized areas. Most materials recovered in the U.S. today are derived from industrial fabrication wastes, but post-consumer wastes are also recovered to some extent (wastepaper, old automobiles) but not in the quantities necessary to bring about a shift in the balance of disposal/recovery. However, the proportion of the nation's materials requirements satisfied from recycling materials has remained constant or has declined in most instances. Some of the reasons for this, the report goes on to discuss, indicate that artificial economic subsidies minimize the recovery of secondary materials; the economics of recycling are also influenced by apparently inequitable freight rates--both ocean and rail--which make the transportation of secondary materials relatively more costly than the movement of virgin resources.

Although technology development is adequate to extract materials and energy from mixed municipal wastes, few full-scale recovery plants exist, primarily because the costs of recovery plants are high, making recovery by technological means attrative only in areas where high disposal costs prevail and local markets for the waste materials exist; and

that recovery by separate collection was judged to be feasible if an existing collection system is used.

The report also indicated that resource recovery results in lower quantities of atompsheric emissions, waterborne wastes, mining and solid wastes, and energy consumption, and as pressure increases to bring about environmentally sound waste disposal, the costs of disposal will rise and recovery will become more attractive as an alternative. Finally, the report indicates that as air and water pollution control regulations are intensified, the incentives of industry for using secondary materials will improve and Federal incentives for recycling do not appear to be desirable to bring about increased resource recovery.

While the second annual Resource Recovery report to Congress is not in final form, the findings and conclusions may be discussed.[15] The second report concentrated on indepth studies of specific waste material streams, taxing and transportation policies and detailed some of the general conclusions drawn in the initial report.

The report indicates that local government is now beginning to seriously consider resource recovery as an alternative to more established solid waste management methods; energy recovery from municipal solid waste is a very viable

alternative; and that the recovery of newsprint and paperboard is a growing opportunity for municipal systems while there are supply and technological problems in recovering glass, metal, rubber and plastic. It is prophetic that these findings occur at a time when the world faces severe energy and materials shortages. These shortages as they intensify will make secondary materials one of the most valuable commodities in our Nation.

Solid Waste Management Manpower. The final direct charge covered in the amended Solid Waste Disposal Act, as amended by the Resource Recovery Act, required the Federal solid waste management program to initiate a manpower study to: determine current and future manpower needs for solid waste management in the U.S., and to report to the Congress on the findings.

The report disclosed that over 300,000 people worked in solid waste management; that only about 350 full time employees were working at the State level; that salaries appeared to be competitive with similar industrial operations; that turnover in unskilled positions was high; that wide variations of employee absenteeism existed; that there was little advancement opportunities because of a very small career ladder; that there were extremely high accident rates

with operating personnel; that there was an available labor pool for the unskilled levels of personnel; and, that significant increases in job numbers were not anticipated.[16]

Continuation of Past Work. In addition to the special studies and reports required by the Congress, the Federal solid waste program (OSWMP) continued to carry out a variety of programs in research, demonstration, planning, and technical assistance.

The demonstration program following over four years of technology studies (1966-1970) gradually shifted to programs to demonstrate the institutional changes necessary to upgrade the management, financing, and operation of local solid waste management systems. Emphasis clearly reflected a shifting of national policy away from the view that hardware/technology could solve the problem to a national understanding that we were not using what we had, and the reasons were not technical, but institutional. Consequently, we are experimenting with a variety of new financing approaches, new organizational arrangements, and utilization of management systems not normally practiced by local government to try to bring about improvements.

During the 1971 to 1973 period, the technical assistance role of the Federal solid waste program emerged as a major factor in improving U.S. solid waste management practices.

Assistance efforts in the collection field were able to clearly illustrate that productivity of the nation's local waste management systems was highly inefficient and that substantial savings could be gained by the utilization of routing and management techniques developed by the Federal program. In city after city, OSWMP professional personnel were able to demonstrate improvement through the application of these techniques.

New techniques for problem assessment and solving were developed by OSWMP. In order to transfer the new techniques developed by OSWMP, a series of programs were launched to train public works officials, consultant engineers, and systems operators in the OSWMP techniques. Coupled with these efforts in the technical and scientific communities, were programs directed to the political decision-makers at the State and local level to stimulate support for changes needed. The major techniques developed, and now being used in technical assistance, include:

COLMIS. The Collection Management Information System (COLMIS) provides information to identify areas of high cost, compares crew and operation performance, estimates the effect of changes in the system, and projects trends. The total information makes up a data bank which is maintained for the ready assessment of operational and cost analysis.

MACRO-ROUTING. Macro-routing is a procedure for determining the optimum assignment of collection routes to disposal facilities.

DISTRICTING AND ROUTE BALANCING. Districting and route balancing is a procedure to determine what a fair day's work is and to divide collection areas into equal workloads for each crew.

HEURISTIC ROUTING OR MACRO-ROUTING. Heuristic or macro-routing is a simple, non-computerized, common sense approach to minimizing the non-collection distance and times for each collection vehicle. Because of its simplicity, heuristic routing has the added advantage of rapid application by local officials.

FIVE-STAGE IMPROVEMENT PROCESS. This process is a logical common sense process which enables a critical evaluation and redesign of collection systems. It guides the user from the initial policy decision and design phases through actual implementation. The five stages of the process are: (1) review policy methodology; (2) determine assignment of collection areas to disposal sites; (3) determine a fair day's work; (4) reroute the system; (5) implement the desired changes and improvements.

Summary

What we learned and what happened from 1966 to 1973 have charted the course of solid waste management in the U.S.A. for the future and particularly for the Federal solid waste program. In summary, the following benchmarks have taken place since 1966.

1. State solid waste agencies have been established, in all states, 43 have developed their plans, the remainder are in some stage of plan completion, and implementation is beginning in many places. Of particular interest is that some States are now beginning to consider and/or establish statewide resource recovery systems.
2. Knowledge of technology has been advanced to the point that we know what can be used and what can't and what are the major questions still needing research and development.
3. Manpower needs are being met without major new development programs.
4. Current systems can be improved by the applications, through technical assistance, of the knowledge we've developed.

5. Resource recovery has become a viable alternative, particularly in solid waste as an energy source.
6. The hazardous and toxic waste management problem has been identified and must be dealt with by vigorous efforts at the Federal and State level.
7. It is now seen that more resource recovery will occur if vigorous enforcement eliminates the cheap and unacceptable options of old antiquated incinerators and open burning dumps.

Finally, we've reached the conclusion that the management of solid waste is actually a "residuals" management activity which must deal with a variety of waste products which require storage, transport, processing, reclamation and ultimately disposal on the land.

1974 and the Prognosis for the Future

Consequently, in late 1973, the Federal solid waste management program focused its initiatives on those program thrusts that utilize the above detailed "knowns," and which will establish long-term directions for State and local programs and a much broader role for the Federal government in "residuals" management.

The Federal program during the next few years will be:

1. Conducting further research, studies and analyses to provide State and Federal government with the tools necessary to regulate disposal operations to assure environmental protection. State government will be pushed to intensify their standard and regulatory authority in solid waste management and will have to establish more vigorous enforcement programs to eliminate dumps. If such State effort fails, the Federal government, no doubt, will have to establish some regulatory control over the land disposal of residuals.

2. Supporting research to assess the environmental impacts of treatment and land disposal practices. Included in this work will be studies of leachate generation, characteristics and control techniques; gas generation, characteristics and control techniques; and the transmissibility of chemical constituents through the soil and aquatic media.

3. Our experience has shown that the cost benefit ratio in technical assistance averages 1 to 10. Technical assistance efforts will therefore be accelerated to assist local systems to improve their productivity in collection operations to

achieve optimum service at minimum costs. Cost savings achieved in the collection productivity side of the ledger can be transferred over to the disposal operations where necessary to provide needed resources to upgrade unacceptable disposal sites.

4. Leading the nation toward the utilization of solid waste as an energy source, since we estimate that there is sufficient energy in residential solid waste to justify this initiative. With the continuing energy deficit that exists in the U.S., the market potential for energy from solid waste is excellent and our program will concentrate as much effort as possible in helping the nation realize that potential.

5. Additionally, our Agency will work with State solid waste agencies to establish State-supported resource recovery systems. This unique and logical approach establishes the State level authority to construct and operate resource recovery systems. This approach takes advantage of several unique characteristics:

    a. Economies of scale

    b. Large State funding authority to raise the mega dollars to build resource recovery facilities.

c. Broader authorities of State government.

6. We will initiate studies and analyses to determine what if any national initiatives should be taken in source reduction. This concept has received some attention by EPA, but studies have not been extensive enough to judge if source reduction is a viable alternative.

7. The final major thrust for the next several years will establish the necessary elements for a national program to properly control and manage those wastes that are inherently toxic; hazardous because of the particular use and application or environmentally degradating. The results of the 1970-73 study clearly indicates the need to place greater control over such residuals. Efforts shall be focused on five areas:

   a. Establishment of the health and environmental effects of these residuals.

   b. Determination of the "chain-of-evidence" necessary to establish standards for treatment and disposal.

   c. Developing the necessary technology and defining the state-of-the-art for treatment and disposal.

   d. Setting guidelines for treatment and disposal.

e. Encouraging state government to broaden their solid waste management programs and authorities to assure proper control and management of these residuals.

These programs are very ambitious and will not be fully effective for some time. However, the past seven years have built a foundation for a viable and effective national effort in solid waste management.

These initiatives must be carried out while legislative decisions are also being made. The current Federal legislation expires at the end of June 1974. Many hearings and debates have already been held, but it is unlikely that decisions on the final nature of legislation will be made by the end of June 1974 and we expect a simple year extension of the existing act. It seems safe to assume, however, that the programs presently underway will fit well into any new act that will be passed.

This lengthy review of our past seven years and projection of the next few years of the Federal solid waste management program clearly indicate that we have moved well along the path to achieving the original purposes of the first Federal Solid Waste Disposal Act. The foundation has been laid. How well the foundation will support the structure we are now building can only be speculated upon. However, we are optimistic; we think we've done our job up to now and we are confident that the future will justify our optimism.

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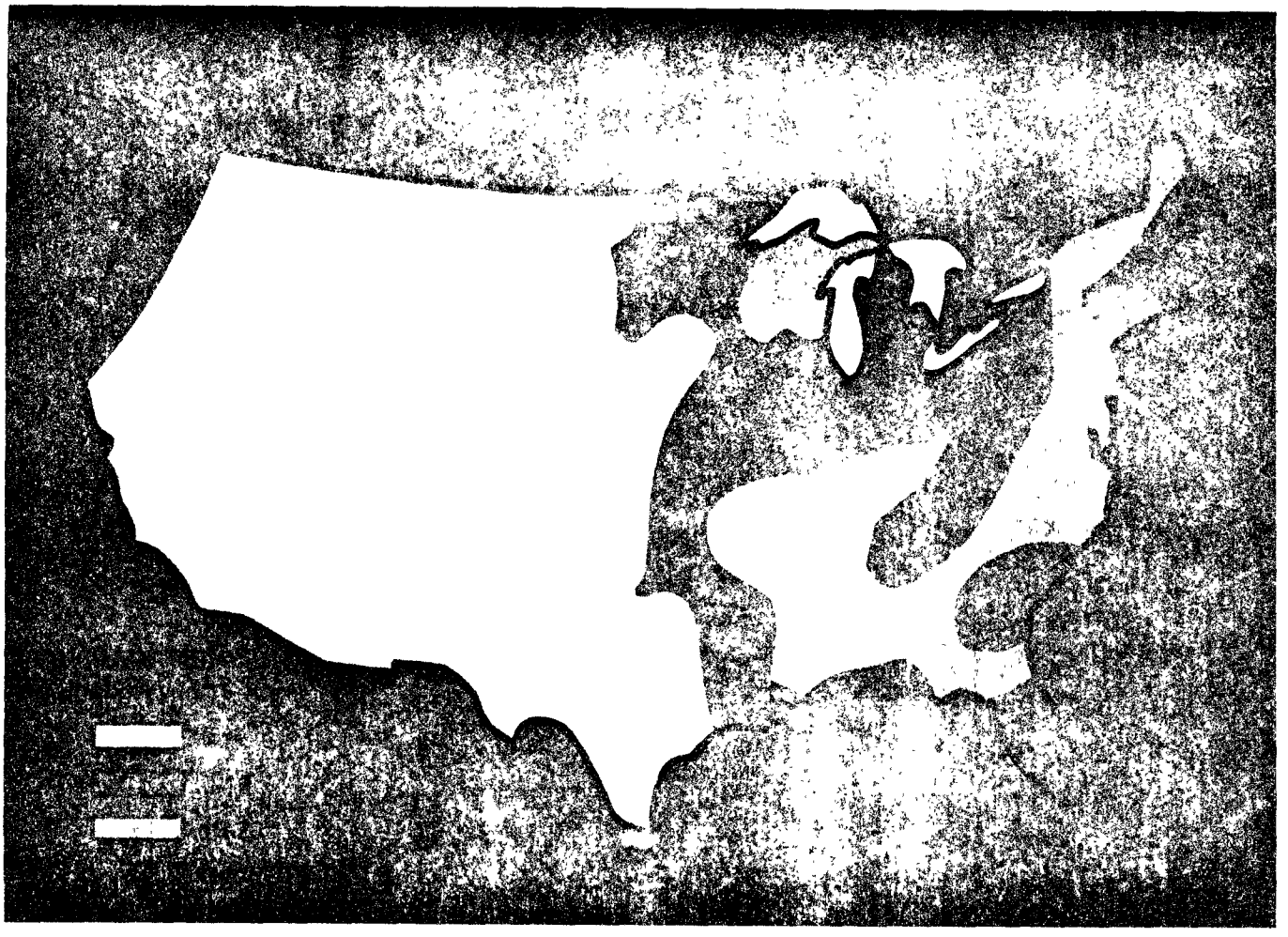

Map indicates where potential leachate infiltration is greatest.

VIII

Dumps: A Potential Threat to Our Groundwater Supplies

Studies by EPA indicate potential groundwater contamination from leachate formed when water percolates through buried trash and garbage. Each city needs to restudy its current and past disposal practices because correcting any damage could prove costly.

BRUCE WEDDLE and GEORGE GARLAND

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the magazine of the National League of Cities

■ A 1972 OFFICE of Solid Waste Management Programs (OSWMP) Survey[1] estimated that there were about 14,000 dumps in operation nationwide.

New information emerging from a damage assessment study now under way by OSWMP indicates that these sites may pose a serious environmental problem.[2]

These findings, in the form of actual damage cases, point out that some of our groundwater resources are threatened by pollutants leaching from dumps.

And if you think that occasional or perhaps even a daily soil cover on your landfill means that you have a *sanitary* landfill rather than a dump, you may be mistaken.

If sanitary landfill design criteria,

For Further Reading

☐ Listed below are several publications which will expand upon the information presented in this article. Sanitary landfill design and operating criteria are presented as well as procedures for closing open dumps.

Brunner, D. R., and D. J. Keller. Sanitary landfill design and operation. Washington, U. S. Government Printing Office, 1972. 59 p.

Brunner, D. R., S. J. Hubbard, D. J. Keller, and J. L. Newton. Closing open dumps. Environmental Protection Publication SW-61ts. Washington, U. S. Government Printing Office, 1972. 19 p.

Hughes, G. M., R. A. Landon, and R. N. Farvolden. Hydrogeology of solid waste disposal sites in northeastern Illinois; a final report on a solid waste demonstration grant project. Washington, U. S. Government Printing Office, 1971. 154 p.

Sorg, T. J., and H. L. Hickman, Jr. Sanitary landfill facts. 2nd ed. Public Health Service Publication No. 1972. Washington, U. S. Government Printing Office, 1970. 30 p.

U. S. Environmental Protection Agency. Thermal processing and land disposal of solid waste; guidelines. *Federal Register*, 39(158): 29327-29338, Aug. 14, 1974.

To obtain a free copy of any of the above publications, write Solid Waste Information Materials Control Section, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268.

For further information write Chief, Technology Application Branch, Office of Solid Waste Management Program, EPA, Washington, D.C. 20460.

including an examination of the soil characteristics and hydrogeology of the site were not considered in its selection and design, then even daily cover and two to three feet of final cover may not be sufficient to prevent groundwater degradation.

With almost 50 per cent of the nation's population using groundwater for domestic use, and with the total demand for groundwater growing, it is of great importance that we begin taking steps today to protect this vital resource.

'No One Ever Died From Leachate'

The environmental impact of open dumping has been oversimplified. The definition of sanitary landfilling adopted for statistical purposes by OSWMP in the above mentioned 1972 survey, and in other OSWMP surveys, includes application of daily cover, no burning, waste not placed directly into groundwater, and no visible pollution of surface water.

But the complex problem of leachate (the liquid produced when water passes through solid waste and flushes out compounds and other products of decomposition) entering unseen into the groundwater was ignored because of the difficulty in obtaining information.

Indeed, the remark reportedly made by one expert in the field that "no one has ever died from leachate" was widely accepted by many as a valid perspective on the leachate problem. In fact, leachate was largely a laboratory curiosity. The ability of some soils to attenuate or cleanse pollutants in leachate may have given some a false sense of security about the "good old dump."

Although there is no epidemiologic evidence to suggest that anyone ever died from leachate, some cases of damage and potential health effects are being found.

The Emerging Evidence

"Groundwater Contamination In the Northeast States,"[3] a recent report published by EPA, summarizes information on 60 cases of damage from dumps (Table 1). These cases were obtained from interviews, public agency files, published sources and unpublished reports. They represent readily available information rather than an exhaustive survey of all sites.

In one case, in Connecticut, a dump caused the wells of about 50 subdivision homes to become contaminated. The subdivision, which was constructed after the dump was established, will now have to be served by an off-site community water supply at a capital cost of $500,000 and an additional annual cost of $55,000.

Perhaps the most serious case became known in Delaware in January of 1972. A homeowner complained that her well water had an extremely offensive taste and odor and contained so much iron that her plumbing fixtures, clothes, and dishes were permanently stained.

An investigation by the Delaware Geological Survey and the local county public works department proved that a dump operated by the county from 1960 to 1968 was the source of contamination. The site, located in an abandoned sand and gravel pit, had been an open burning dump during part of its history, and various in-

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City Officials Address EPA Leachate Position

The following brief comments are reactions by a mayor, a city manager, and a sanitation director to the EPA leachate story on these pages.

A Mayor . . .

Apparently, EPA has chosen to bite the bullet on solid waste. The research supporting this article indicates clearly that solid waste management is a national problem and deserves more attention than it's been getting.

Actually, the article underscores recommendations made earlier this year by the NLC and USCM Solid Waste Task Force.

Calling for increased attention to conventional areas of municipal waste management, the Solid Waste Task Force urged the establishment of a National Center for Research in Waste Management with an advisory board composed of local, state and private representatives. Research activities should address a full range of disposal problems, such as leachate studies and testing, and extensive work on improved methods of sludge disposal.

The Task Force also recommended an expanded technical assistance program for all major aspects of solid waste management-collection, processing, disposal, materials and energy recovery. In light of the increased cost burden imposed upon local governments for all environmental control programs, a fully funded program of technical assistance represents a minimal level of effort for the federal government.

Finally, this article is another exhibit in the case for immediate legislative action by the Congress, with adequate funding for technical assistance, applied research and resource recovery demonstrations.

John G. Hutchinson, Mayor
City of Charleston, W. Va.
Chairman, NLC & USCM
Solid Waste Task Force

A Sanitation Director . . .

The article makes several points which I think are helpful. First, that overzealous citizen groups opposing sanitary landfills can thereby unwittingly perpetuate the environmently insulting dumps.

Prior approval of landfills by appropriate state agencies is becoming a well established procedure which insures that full

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dustrial wastes had been accepted along with municipal wastes.

In 1970 the site was covered with 2 to 5 feet of earth. Nevertheless, an underground plume (flow) of leachate had enveloped her well and was extending 1,500 feet toward the well field of a water company serving 80,000 people.

The company had to reduce its pumping rate and interceptor wells were installed near the 60-acre dump. The leachate migration has been stopped by pumping the interceptor wells and a number of individual wells have been replaced. To completely remedy the situation, which will take at least 10 years, the county will probably have to spend more than $20 million.

Of course, the problem does not make itself so obvious as in the Connecticut and Delaware cases. The U.S. Geological Survey has been investigating a number of groundwater pollution incidents, including a case on Long Island, N.Y., where the leachate from a dump moved with the groundwater flow for two miles. One mile from the site the selenium concentration in the groundwater still exceeded drinking water standards.

How Does It Happen?

The production of leachate is a complex process involving many variables (Figure 1. Simply stated, leachate is formed when water percolating through solid waste flushes out compounds and other products of decomposition.

Rain falling over a disposal site will partially infiltrate and partially run off the surface. A portion of that water which infiltrates will be used to meet the demands for evapotranspiration (soil evaporation and plant transpiration); the remainder will percolate down through the soil into the buried solid waste.

Initially, the solid waste acts as a sponge and simply absorbs the water. However, with the continued addition of rainwater the waste eventually reaches the limit of its moisture retaining capacity. At this point, any further water entering the waste will cause an equal volume of contaminated water (leachate) to leave the waste.

The process is greatly accelerated at open dumps where soil cover is not provided, because runoff is greatly reduced, thereby increasing infiltration and leachate production.

The water necessary for leachate production comes not only from precipitation but from liquid waste disposal at the site, moisture in the waste, water running onto the site from adjacent properties, infiltration from irrigation above the site (e.g., excessive watering of a golf course built over the site), and from surface or groundwater moving through the waste.

The map in Figure 2 shows those areas of the country where one would expect net infiltration from precipitation into the solid waste at a disposal site. This map shows those areas of the country where potential infiltration (a measure of the annual amount of water that percolates down through the soil after runoff and evapotranspiration demands are met) is greatest.

Although runoff is important, it was ignored in the map since its effects vary with local conditions.

As shown, infiltration and the resulting leachate formation is potentially greater east of the Mississippi River and in the Pacific Northwest than in the rest of the country. Dumps located in areas of zero or negative potenial infiltration may also produce leachate, especially if they are in direct contact with ground or surface water.

Additionally, if rainfall comes at one time of the year, some leachate could be produced even though the annual potential infiltration for that area was zero.

How Much Leachate Is Produced

The average dump in this country covers 17 acres.[4] Thus theoretical calculation assuming 10,000 of the estimated 14,000 dumps being used in 1972 received an average of 10 inches of infiltration annually, shows that those dumps could have produced over 46 billion gallons of leachate during that year. (We'll assume the other 4,000 dumps are in the "zero" infiltration zone).

What happened to this leachate and how much reached the groundwater depended on the type and amount of soil under the site, the operation of the site, and the initial design and location of the site.

Whether the leachate could cause a problem depends on the attenuation ability of the soil and present or proposed groundwater usage around the site.

The Alternative

Up to this point the detrimental effects of open dumping and improper landfill practices that occur in most communities today have been discussed. Now let's examine sanitary landfilling which is the only proven, environmentally acceptable method of final disposal available.

The term "sanitary landfill" has

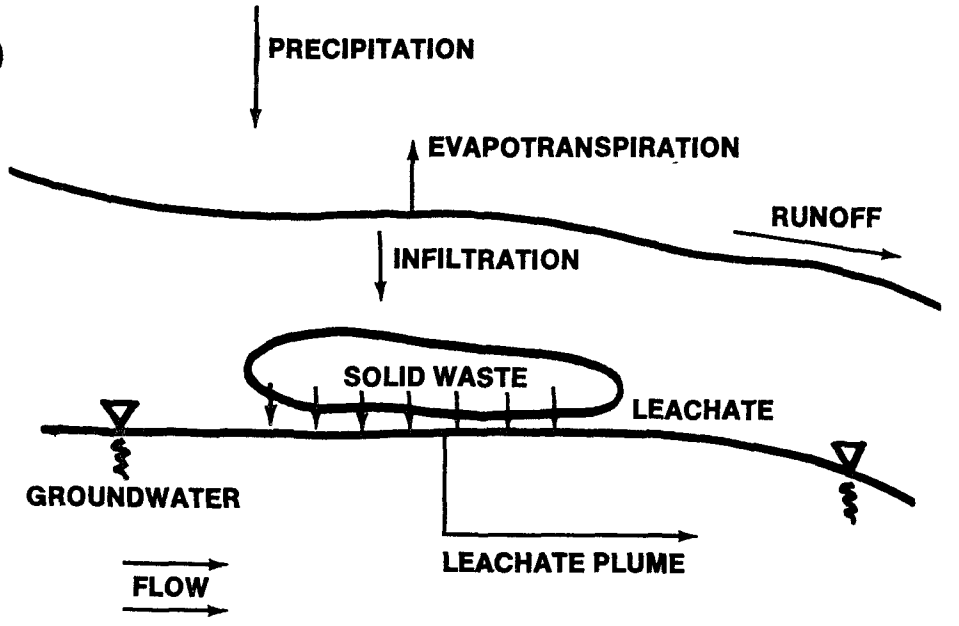

Figure 1
The process of leachate formation.

been abused. A common definition—a disposal site where solid waste is buried under six inches of daily earth cover and two to three feet of final earth—is misleading.

Sanitary landfilling is more than the cosmetic disposal of waste. Disposal sites, no matter how well run, are not sanitary landfills unless detailed subsurface criteria were met in selecting the site.

Specific steps communities should take are outlined in OSWMP's publication *Sanitary Landfill Design and Operation* and in the other publications listed (see box, page 22). These publications recommend thorough evaluation of site characteristics such as:

- depth from the bottom of the fill to the maximum height of groundwater
- direction and flow rate of groundwater
- present and future groundwater demands
- an analysis of underlying soils and geology including texture, permeability, structure, and stratigraphy
- topography (surface drainage)
- net infiltration.

State solid waste management agencies are another valuable source of assistance and advice during the evaluation, selection, and design of sanitary landfill sites. Coordination with these agencies should be considered an essential first step in the site selection process. Their participation will facilitate the selection of an environmentally sound site and minimize the time necessary to meet permit regulations.

The Irony of It All

Sanitary landfills are designed to control leachate. Careful attention is paid to underlying soil and hydrogeological conditions, cover permeability, and types of solid waste to be placed in the fill.

Some states require collection and treatment of leachate where natural conditions are unsuitable for land disposal without special precautions. These various measures make the chance for damage from sanitary landfills extremely remote. Yet a few citizens and environmental groups are using the fact that zero discharge cannot be 100 per cent assured as a basis for defeating proposals for new sanitary landfills.

If it is really a sanitary landfill they are opposing, they are unwittingly perpetuating the environmentally insulting open dump.

Further compounding site selection problems are those groups who advocate that resource recovery techniques can replace the need for closing open dumps and establishing sanitary landfills. Although resource recovery is a worthy goal, and can result in great reduction of the volume of wastes requiring disposal, today it cannot replace the need for environmentally sound land disposal.

Moreover, even the most complete and effective systems of resource recovery that can be envisioned for the future will still leave large residues of unusable wastes which must be disposed of, on land, and in ways that do not pollute.

It therefore is ironic that these groups, dedicated as they are to protecting our environment, are actually contributing to the degradation of the environment by prolonging the use of dumps.

New Site Selection

Application of the sanitary landfill criteria referred to above makes early attention and foresight in site selection even more critical. In too many cases the search ends with the selection of an environmentally undesirable site because the old site just can't accept any more waste.

To ease this crisis decisionmaking atmosphere, communities should strive toward a goal of maintaining at least five years of disposal capacity on hand at all times.

Sites with good natural soils and favorable hydrology should be set aside even at some political cost. In the long run this step will provide the multiple benefits of lower land acquisition costs, improved planning

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Table 1.
SUMMARY OF DATA ON 42 MUNICIPAL AND 18 INDUSTRIAL DUMP CONTAMINATION CASES

Findings	Type of Dump: Municipal	Industrial
Assessment of principal damage		
Contamination of aquifer only	9	8
Water supply well(s) affected	16	9
Contamination of surface water	17	1
Type of pollutant observed		
General contamination	37	4
Toxic substances	5	14

Source: Groundwater Contamination In The Northeast States, David Miller, Frank DeLuca, Thomas Tessier, U.S. Environmental Protection Agency, Office of Research and Development, June 1974.

Dumps: A Potential Threat

Continued from page 25

and, most importantly, selection of an environmentally sound disposal site.

The need for sanitary landfill sites must also be recognized in land use planning efforts. Such efforts often set aside land for educational, recreational, transportation, commercial, utility, and other uses. Similarly, land use plans should identify acreage to be used for solid waste disposal, an indispensable community service. Conscious planning for solid waste disposal will help prevent the common relegation of disposal to environmentally unacceptable (but more rapidly available) sites.

What About Existing Sites?

It is incumbent upon each responsible local official to reexamine his community's current and past disposal practices. Failure to do so could result in the loss of the groundwater as a resource and may, as it did in the one case in Delaware, result in a costly cleanup program. Indeed, the community may be legally responsible for any damage caused by improper disposal at its site.

A good place to begin would be to determine what hydrogeological information, if any, was used during site selection. Specifically, were the sanitary landfill site selection criteria followed?

In those sites where these criteria were not followed, an evaluation should be made, possibly including test wells, to identify the subsurface conditions and to monitor for the presence and movement of leachate. If leachate is discovered in the groundwater, steps should be taken immediately to access the extent of the leachate flow and the potential threat to users of that groundwater. Then an examination of alternative control methods should be initiated if necessary.

The above recommendations for obtaining new sites and monitoring existing sites are easier to state than to implement. They will increase direct disposal costs.

In the long run, however, it will be to the advantage of the community to identify and prevent degradation of our increasingly valuable groundwater resources. The alternative to these recommendations may carry a financial risk far greater than the cost of prevention. ■

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Leachate Reaction from City Officials

Continued from page 24

consideration is given to environmental, engineering, ecological and other community concerns.

Economic considerations, which have always had a vital bearing, are now becoming increasingly difficult. This, along with our increasing knowledge of the effects of leachate traveling through specific subsurface soil conditions, could expedite a trend toward providing customized protection to each sanitary landfill on a more individualized and enlightened basis.

John Teipel, P.E.
Director
Street and Sanitation Services
City of Dallas, Texas

A City Manager . . .

To ignore the possible effects of leachate is as irresponsible as to condemn a true sanitary landfill Property owners, environmentalists, and city officials should note the distinct difference drawn by this article and prepare for the continuation of land disposal of some solid waste for many, many years into the future.

Tom Osborne
City Manager
City of Greensboro, N.C.

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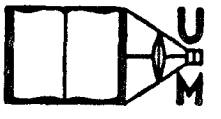

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IX

HAZARDOUS WASTE MANAGEMENT IN THE UNITED STATES

By

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For Presentation
At
The Second Joint U.S. - Japan Conference
on Solid Waste Management
Washington, D.C.
September 25, 1974

Historically, solid waste has been perceived as municipal trash and garbage. It was thought that if we could eliminate the rats, flies and open burning associated with open garbage dumps with sanitary landfill practices, the problem would be solved. Indeed, the term "sanitary" associated with landfill connotes a hygenic condition which is rarely achieved and can be misleading to the public.

More recently, municipal solid waste has been considered as a possible source of materials and energy. In the United States, the amending of the Solid Waste Disposal Act by the Resource Recovery Act in 1970, (PL 91-512)[1] provided a new thrust for the solid waste management program towards recovery of valuable materials and energy from waste residuals. Some progress has been made in this area and much more is anticipated.

But industrial wastes, some of which are toxic and hazardous, have been largely ignored because traditionally these wastes are managed outside the municipal solid waste collection and disposal system. However, much of these wastes end up at the same disposal site as municipal solid waste.

Hazardous waste includes toxic chemicals, pesticides, acids, caustics, flammables, explosives, biological and radiological residuals. In EPA's Report to the U.S. Congress on Disposal of Hazardous Waste in 1973,[2] we estimated the total amount of non-radioactive hazardous waste generated in the United States to be approximately 10 million tons per year, or roughly 10 percent of all industrial waste. OSWMP studies now underway indicate this number may be much greater.

According to our studies, the primary source of hazardous wastes is the industrial sector. Examples of industry sources include: chemicals, pesticides, petrochemicals, drugs, primary metals, nonferrous metals, electroplating and batteries. Of course, this is a sample list and there are many other industries which produce hazardous wastes. But industry is not the only source. Installations of the U.S. government and other

institutions, such as hospitals and laboratories, also generate hazardous wastes.

Only in the past few years have the public health and environmental effects of improper solid waste disposal to the land come under serious study. This problem is manifested in groundwater contamination by leachate, surface water contamination from runoff, air pollution from open burning and evaporation, food contamination from improper storage, and, of course, personal injury from direct contact and explosions which may result from the mixing of wastes in unacceptable landfill operations. OSWMP has on record a large number of such incidents from various sources as noted in the following examples.

- As a result of burying arsenic-containing pesticides in Minnesota in the late 1930's, eleven persons developed symptoms of arsenic poisoning in 1972 after drinking contaminated well water. Two of the victims required hospitalization and treatment.[1]

- For several years, a large municipal landfill in Delaware accepted both domestic and industrial wastes. In 1968, this disposal site was closed and forgotten about for four years before chemical and biological leachates were detected in the

nearby groundwater. According to current estimates, up to $26 million may be required to stop further deterioration of the underground aquifer which serves as a drinking water supply to over 40,000 area residents.

• From 1953 to 1973, a laboratory company in Iowa utilized a dump site for solid waste disposal. Over 250,000 cubic feet of arsenic-bearing wastes have been deposited there. Monitoring wells around the dump have established over 175 ppm arsenic in the groundwater. The U.S. Public Health Service recommended drinking water standard for arsenic is 0.05 ppm. The dump site is located above a limestone bedrock aquifer, from which 70 percent of the nearby city's residents obtain their drinking and crop irrigation water. Although there is no evidence that the drinking water is affected, the potential public health problem is obvious.[2]

• 20,000 head of cattle were quarantined in Louisiana because they had eaten grass contaminated by hexachlorobenzene (HCB) which had sublimed from a nearby dump.[2] In addition, children have been poisoned by the improper use of pesticide containers, workers at dumps have been injured by explosions, and in short, every year turns up new ways in which the disposal of hazardous

wastes can injure people.[2] This problem can appear within a relatively short time, as happened in Delaware, or it can take decades to appear as was demonstrated in Minnesota. It can strike quickly in the form of acute poisoning, or it can cause slow chronic poisoning over a lifetime without the victims' awareness.

We see an increasing opportunity for adverse impacts from hazardous waste disposal from at least three sources. The first is the expansion of industrial production in most industrialized countries, which is tied directly to hazardous waste generation. Next is the transfer of hazardous materials from other media to the land as a result of air and water pollution controls. Lastly, is the increase in hazardous waste materials destined to the land as a result of ocean dumping controls and bans on certain materials, such as the recent cancellation in the United States of most registrations for DDT pesticide. Taking all these sources together, we estimate that the growth of hazardous waste generation in the United States will be between 5 and 10 percent per year.[3]

One could ask who causes this problem and how and why. In our studies to date, we have established that the problem is

caused mostly by some waste generators who use improper disposal procedures either on-site, that is, on their property, or off-site through contract haulers, and that these improper acts are either purposeful or accidental. Also, we have found that waste haulers sometimes use improper disposal methods in an effort to reduce costs and improve their profit. Lastly, those that are in the business of treating and disposing of hazardous wastes sometimes use improper techniques.

Adverse impacts to the public health and the environment occur because of open dumping and burning of hazardous wastes or improper use of existing land disposal sites. These actions can be either overt or covert. Also, improper use of holding ponds on industrial land and improper storage techniques cause problems.

We believe that the reason this situation exists is that there are no widespread economic or legislative incentives for hazardous waste management.

In the United States we have found that technology is adequate for the treatment of many hazardous wastes by physical, chemical, thermal or biological means. There are secure storage

facilities available for those few wastes to which current treatment technology does not apply.

The main problem is that the use of this technology is expensive and far exceeds the cost of current unacceptable practices. For example, the incineration of hazardous wastes can run as high as $50 per ton, whereas the current inappropriate practices of open dumping or ocean dumping costs approximately $3 per ton.[3] So, we have a wide cost variation between hazardous waste management practices which are acceptable versus those that are generally used.

These cost differentials have implications towards the international balance of trade. If one country were to insist on proper hazardous waste treatment at higher costs, this would to some degree put that country's industry at a competitive disadvantage with similar industries in countries which did not have such high standards.

As we mentioned before, however, the management of hazardous residues is emerging as a major problem for all industrial societies. Several international organizations have recognized this and are beginning to develop hazardous waste

management guidelines. Draft procedures for proper hazardous waste disposal and storage were developed by a recent working group conference of the World Health Organization. Hopefully, through such international cooperative efforts, all industrialized countries can achieve common guidelines for hazardous waste management practices.

Let me now turn to the hazardous waste management programs currently in being in the United States. We have reached the conclusion that environmental insult and hazards from improper waste management will continue in the absence of strong regulation of land disposal and vigorous enforcement of regulations where they exist. So long as inertia, indifference or economic pressures still tilt the balance toward improper disposal; so long as no consistent and uniform rules exist for public and private operation, and so long as offending sites cannot be closed because no alternatives exist, then the necessary transition from poor environmental management to optimum management will not take place. For this reason, and because talk alone appears insufficient to achieve acceptable standards, we believe that government regulation of hazardous waste management is essential.

Hazardous wastes must be controlled from the cradle to the grave in order to achieve effective hazardous waste management. It is not sufficient to regulate only the land disposal phase, since many uncontrolled pathways to the environment would still exist.

Unfortunately, the land disposal of hazardous wastes is essentially unregulated at the Federal level and in most States. Consequently, EPA has already reached the decision to seek a Federal standard-setting and regulatory role in the hazardous waste area. Early in 1973, we proposed the Hazardous Waste Management Act.[3] If passed it would provide for State regulation via permit of hazardous waste generation, transportation, storage, treatment, and disposal under Federal standards, and it would permit direct Federal regulation of some extremely hazardous wastes at the discretion of the Administrator of EPA. This approach generally follows the precedent of the Federal Clean Air Act (PL 91-604).

The basic elements of the Hazardous Waste Management Act have been included in several other pieces of proposed Federal legislation. From the various pieces of legislation under consideration, it is hoped that some form of regulatory control

of hazardous waste management at the Federal level will be provided. The nature and character of that responsibility is unknown at this time.

To prepare for a standard-setting role under the proposed Hazardous Waste Management Act or similar legislation, the Federal program thrust at this time is aimed at three main areas.

First we are vigorously building a data base in the hazardous waste management area. This effort has three sub-elements including public health and environmental damage assessment; hazardous waste quantification, that is, a fundamental knowledge of what hazardous wastes are, how many and how much there are, and where they are; and lastly, technology assessment attempting to define all possible treatment and disposal technologies for hazardous wastes. The three basic technical options for hazardous waste management are incineration, chemical treatment and special landfill. We intend to study all three of these options in some depth in the coming years by demonstration grants and contracts.

The second major thrust is in guidelines and standards development. Under the Federal Insecticide, Fungicide and

Rodenticide Act, as amended in 1972, (PL 92-516) we already have the authority to issue procedures and regulations concerning the disposal and storage of excess pesticides and pesticide containers. The first publication on this subject, which is a statement of EPA's recommended procedures for pesticide disposal and storage, appeared in the Federal Register on May 1, 1974. At this time we are preparing regulations which will prohibit the worst pesticide disposal and storage acts such as open dumping, open burning, etc. Proposed rulemaking on this subject should be published in late 1974. Next, under Section 209 of the Solid Waste Disposal Act, as amended by the Resource Recovery Act of 1970, we have the authority to issue guidelines for solid waste management practices. We are developing hazardous waste guidelines similar to those for land disposal and thermal processing of municipal solid waste, which the Office of Solid Waste Management Programs published on August 14, 1974. We have established no firm date for the publication of the hazardous waste management guidelines since they are somewhat dependent upon data base development activities.

Our third main thrust is in program implementation. Here we have three main sub-areas. In the policy analysis area we are looking into what the Federal, State and private sector roles

should be in hazardous waste management, and other issues of this type. Next, in the State implementation area, working through EPA's regional offices, we are attempting to aid and assist those States that already have hazardous waste programs, to spur those that don't, and in general to provide as much help to the State governments in this area as we possibly can. Lastly, in the area of technical assistance we have a small but competent technical staff capable of responding to requests from all sources. Currently, we have many requests for assistance on the disposal of hazardous wastes from EPA regional offices, other Federal agencies, State governments, private industry and from private individuals.

At the State and regional level in the United States we are seeing an awakening towards the hazardous waste management issue. Several of our larger industrialized States have already passed State legislation which regulates hazardous waste disposal and storage. The State of California has already implemented such a program and the States of Illinois and New York are close behind. Also, we have seen recently the emergence of a publicly chartered regional authority for treatment and disposal of hazardous wastes at the Gulf Coast Waste Disposal Authority in the Houston area.

In the last two years or so there has been a significant change in the role of the private sector in the United States. We have seen the emergence of large corporate industries operating over extended geographies making use of modern management techniques and taking advantage of economies of scale. Some private waste contractors have diversified to assume new functions in recovery and hazardous waste processing. Also, some large firms have invested in their own hazardous waste management facilities. Examples are Dow Chemical Company in Midland, Michigan, 3-M Corporation in St. Paul, and the Eastman Kodak Corporation in Rochester, New York.

Before I close I would like to leave you with some of our philosophy concerning hazardous waste management. We have attempted to establish a reasonable scenario for hazardous waste flow after generation. Our philosophy, as the land protection group within EPA, is to minimize hazardous waste disposal to the land. However, in the long run, we don't believe that improved disposal technology is the real answer. Every industrial nation is finding it harder to get raw materials. Even American industry, which was blessed for so long with a cheap, seemingly infinite supply of domestic raw material, is now importing and carefully husbanding much of its supplies as Japanese industry

learned to do a long time ago. Industrial wastes can be eliminated by process improvements, or they can be recycled, or used as feed stock for other industries. The ultimate solution to the problem of hazardous wastes is not to have any. And we see the development and enforcement of safe, environmentally clean disposal techniques as a means by which the government fosters this end, rather than an end in itself.

Our main strategy will be to concentrate hazardous waste at the source rather than to dilute them into the environment. Hazardous waste concentration minimizes handling and transport problems, makes resource recovery from these wastes economically more attractive, and allows better management control. Such concentration will occur naturally as air and water pollution control systems extract noxious pollutants from waste flow streams. Also, product bans, such as DDT, will result in large, concentrated stocks of excess materials.

We support the concept of a hazardous waste clearing house, that is, to use the waste as is, if possible. One man's waste is another man's feed stock. A firm in Berkeley, California, was recently formed to provide this service for the

western area. The clearing house concept has been adopted recently in Scandanavia and West Germany, as well.[4,5]

Many hazardous wastes contain valuable basic materials, some of which are in short supply. Material recovery makes sense from both resource conservation and environmental points of view. Extraction of materials from concentrated waste generally requires less energy, and generates far less air and water pollution, than the mining and processing operations required to produce the material from virgin resources. As material shortages become more widespread, material recovery from hazardous waste will become more economically attractive. Even so, we know of one eastern firm that actually buys industrial waste for material recovery right now.

If hazardous waste cannot be used or materials recovered from it, and if it can be safely burned, we would next recommend destruction by incineration with energy recovery during this operation, if possible. Incineration of hazardous waste generally requires special, high-temperature equipment with effective scrubber systems and effluent monitors. Several large corporations and waste processing firms have these incinerators

in operation now, but they are not commonly available throughout the nation as yet.

Non-burnable wastes should be detoxified and neutralized by chemical or biological treatment, where possible, to minimize the amounts of toxic materials destined for land disposal.

For hazardous wastes not amenable to recovery or destruction, we recommend volume reduction to minimize land use requirements, followed by isolation techniques, such as encapsulation, prior to land burial in specially designated landfills which in turn may be isolated from groundwater supplies by natural geologic formations or artificial membranes. Monitoring and surveillance systems are required for such landfills to detect any leachate and prevent unauthorized entry.

Let me summarize our perceptions of the hazardous waste management situation in the United States at this time. First, we now know that we have a problem, a major problem which is common to all industrial nations, and that this problem is growing due to several factors. We have found that the technology for adequate hazardous waste management generally exists for many hazardous wastes but that this technology is

costly, approximately 10 to 40 times as expensive as current unacceptable practices, which consist mainly of landfilling or ocean disposal.[3] Consequently, there are no incentives for the use of this technology and, furthermore, there are no strong regulatory incentives at either the Federal or most State levels.

Consequently, a regulatory strategy for the management of hazardous wastes is under development. This program will require a joint Federal, State, and private sector response. We see a lengthy period during which legislation and regulations are developed and facilities are made available, but eventually we would foresee a regulatory program with adequate enforcement to prevent the potential public health and environmental damages which can occur from improper management of these wastes.

The United States is working together with other industrialized nations to develop common guidelines for acceptable hazardous waste management practices. This is a new and growing field but we have confidence that the hazardous waste management program of all industrialized countries will reach a level where the public health and environmental effects of hazardous waste will be under adequate control.

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RESOURCE RECOVERY IN THE UNITED STATES

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Introduction

It is a great pleasure to be here this morning to share a few thoughts with you about resource recovery. In the past year, we have witnessed significant strides in the solution to the nation's solid waste problems, particularly in resource recovery. Ironically, the great strides of the past year were the result of the existence of a new problem, the energy and materials shortages. In other words, the energy crisis advanced resource recovery substantially because cities and states saw municipal waste as a new source of energy, ferrous metals, non-ferrous metals, and glass.

Since Earth Day 1970, man has questioned his previously uncontrolled growth--in technology, industrialization, urbanization, consumption of resources and population--questions for which he had no immediate answers. One of the problems caused by unchecked growth was environmental pollution.

Resource recovery was seen as a solution to two of the above problems, environmental pollution and consumption of resources. For the next three years, much groundwork was laid, but little progress at the municipal level was seen. The Energy Crisis of 1973 legitimized resource recovery because many people realized that municipal solid waste is a legitimate source of raw materials and energy.

Energy and Materials Content in Solid Waste

Energy Savings - The potential energy savings is derived in two ways: (a) direct conversion of the combustible portion to energy (energy recovery) and (b) energy savings derived from consuming recycled materials in production processes (materials recovery) such as glass and metals.

Direct conversion of waste to energy can produce significant energy. More precisely, if resource recovery systems had been operating in the more densely populated areas, such as the Standard Metropolitan Statistical Areas (SMSA's) in 1971, over 830 trillion BTU's would have been recovered. This is equivalent to 390,000 barrels per day of oil. This should grow to 510,000 barrels per day by 1980.

The energy savings derived from consuming recycled materials in production processes is also noteworthy. We have identified these savings by comparing two production processes--one using virgin materials and the other using recycled (secondary) materials. We have made these comparisons for steel, aluminum, glass, and other production processes. The production processes consuming recycled materials usually consume less energy than systems consuming virgin materials--when all stages of materials, acquisition, processing, and transportation are included.

The energy savings from using recycled rather than virgin materials in the production processes for aluminum, ferrous, and glass are:

Material	Energy Savings Over Virgin Material Process
Aluminum	87 - 97 %
Ferrous	50 - 60 %
Glass	5 - 15 %

If these materials had been extracted from municipal solid waste in 1972 in the SMSA's, almost 14 million tons of steel, aluminum, and glass would have been recovered and substituted for their virgin material counterparts.

Such a substitution, based on preliminary estimates, would have yielded a national energy saving of the equivalent of 80,000 barrels of

oil per day. This has been estimated to rise to approximately 120,000 barrels per day in 1980.

Thus, the total energy savings from resource recovery is:

	Energy Savings*	
	1971	1980
Energy Recovery	390,000	510,000
Materials Recovery	80,000	120,000
Total	470,000	630,000

*Barrels of oil per day equivalent

The Compatibility of Energy Recovery, Materials Recovery, and Source Separation

Since the energy crisis began, many have used the term energy recovery to mean resource recovery. I feel it is important to use the proper term, resource recovery, because some people feel that when EPA promotes the concept of energy recovery, we are against materials recovery and source separation of newsprint. Nothing could be farther from the truth. We are encouraging local governments to evaluate all three concepts because they are all compatible with each other. Energy recovery techniques can be employed to reuse much of the waste that cannot be reclaimed by materials recovery or source separation.

Another way of looking at it is that most energy recovery technological approaches separate the combustibles from the non combustibles to upgrade the quality of the fuel. The non-combustible portion is composed primarily of metals and glass. And it is often cheaper to recover the metals and glass rather than landfilling them! Consequently, all three approaches should be considered.

Power Utilities - Interest in Energy Recovery

As I have indicated, the potential energy that can be converted from municipal solid waste (roughly the equivalent of 400 thousand barrels of oil per day) is not an overwhelming amount of energy. Yet, 400 thousand barrels of oil is significant when expressed as:

a. 5 1/2 percent of fuel consumed by all utilities in 1970

b. 6.7 percent of all fossil fuel consumed by utilities in 1970

c. 11 percent of all the coal consumed by utilities in 1970

d. 27 percent of oil projected to be delivered through the Alaskan Pipeline

e. 40 percent of the crude oil imported from the Middle East in September, 1973

f. 1 percent of all energy consumed in the U.S. in 1970 (32.5 million B/DOE)

The four hundred thousand barrels of oil is not insignificant when put in the perspective as being equivalent to 11 percent of coal consumed by utilities in 1970. A recent Gordian Associates study "Where the Boilers Are" commissioned by EPA, examined this issue in greater detail. The study surveyed electric utility boilers, on a boiler-by-boiler basis, with potential capacity for burning solid waste as a fuel. It covered the major coal-burning states and urban centers which account for over 90 percent of the coal consumption for power generation. The information given for investor-owned and municipally-owned plants includes the following:

a) Boiler characteristics

b) Energy requirements for electricity generation

c) Potential energy availability from solid waste from surrounding area

d) Typical transportation distances from centers of waste generation to the plants.

The results of the study provide several important insights. Although the potential energy supply from refuse is 6.7 percent of fossil fuel consumed by all utilities nationally, it is substantially higher in some regions:

Region	Potential Utility Energy Supply From Refuse (fossil fuel plants)
Massachusetts	13%
Maryland	8%
Minneapolis	10%
New Jersey	9%
New York	14%
Rhode Island	43%

Examination of only coal burning plants producers results that are even more dramatic:

Region	Potential Utility Energy Supply From Refuse (Coal-burning Plants)
Florida	24%
Illinois	8%
Massachusetts	19%
Minneapolis	10%
New Jersey	10%
New York	19%

Future Plans of Union Electric

Union Electric, the electric utility involved in the St. Louis "refuse to energy" demonstration has recently announced plans to build, own, and operate a $70 million transfer station and resource recovery system to serve the entire St. Louis metropolitan area. It will be capable of handling 8,000 tons of waste per day. This committment surely indicates Union Electric's confidence in the concept.

At the same time, Combustion Engineering announced plans to build 12 pre-engineered utility refuse-firing modules. They could be used for coal-fired and oil-fired systems. The modules would be capable of firing up to 20% solid waste on an energy input basis.

Connecticut

The Connecticut Resource Recovery Authority recently announced plans to build two resource recovery systems that will process 3600 tons per day of waste. The plants are projected to recover 80,000 tons per year of ferroue scrap, 4,000 tons per year of aluminum, 40,000 tons per year of glass, and a fuel that will be sold to utilities. The fuel will represent 10% of the utility fuel required by each region. The fuel of the Bridgeport processing plant will be sold to Northeast Utilities' Devon plant as a supplementary fuel. The New Britain plant will produce a fuel product that will be sold to Wallingford's Pierce power station as its primary fuel.

Net disposal cost for the communities participating in these systems will be a maximum of $10 to $12 per ton, including operation of the transfer stations. Refunds from the sale of products could reduce the dump fee by $3 to $5 per ton.

The total guaranteed maximum costs, which include transfer station costs, will be about $4 per ton more. However, this should be reduced by shared revenues of $3 to $5 per ton. To summarize:

Guaranteed Maximum Cost			Expected Additional Revenue	Expected Net Cost
Transfer Station	Processing & Recovery	Total		
$4	$5 to $8	$9 to $12	$3 to $5	$4 to $9

Note that the processing and recovery costs of $5 to $8 per ton include some revenue from the sale of recovered materials. However, because it is a guaranteed maximum net cost, fairly conservative prices for energy and materials are utilized. The expected additional revenue of $3 to $5 per ton reflects existing prices (higher than base prices) for the recovered products.

Future adjustments will be made to these charges because of inflation. The future charges will be determined by formula negotiated at the beginning of the contracts. The formula includes costs that can be affected by inflation such as labor costs and equipment costs. Adjustments will be determined by wage and other cost indices. Some costs, such as utilities and taxes, are not included in the formula because they cannot be controlled by the operator of the plant. These costs will be adjusted as they occur.

The disposal cost of the Hempstead, Long Island system has been projected to be in the $9 to $12 per ton range. The Sangus, Massachusetts facility's disposal cost will probably be in the $11 to $14 per ton range.

Other Utilities

The interest of other utilities in shredded fuel has been substantial. Two utilities, in Chicago, Illinois and Ames, Iowa have committed to burning waste in their power plants. The solid waste processing facilities are now being built in these cities. We are aware of over 30 other utilities studying the concept's feasibility.

Utilities are interested also in other waste to energy systems. San Diego Gas and Electric has committed to purchase the oil-like liquid that will be produced by an EPA demonstration in San Diego County. SDG&E made the committment after receiving satisfactory combustion test results of samples made from the pilot process.

A resource recovery facility to be built in Hempstead, Long Island will utilize solid waste as the primary fuel to produce electricity that will be sold to the local utility. Another EPA demonstration in Baltimore will use a pyrolytic process to produce steam that will be sold to Baltimore Gas and Electric which produces electricity, heating and cooling to downtown buildings. In Nashville, Tennessee, the Nashville Thermal Corporation, a quasi-public corporation, will produce chilled water and steam for over 40 customers, including hotels, commercial office buildings and government buildings. A waterwall incinerator will be used to convert solid waste to chilled water or steam.

Future Concepts

Newer concepts that are being evaluated include gas pyrolysis and methane production. Several companies are developing gas pyrolysis systems. Union Carbide is constructing a 200 ton per day facility in South Charlestown, West Virginia. The process will utilize pure

oxygen rather than air. The resultant gas is a clean burning fuel comparable to natural gas in combustion characteristics, but with a heating value of about 300 BTU's per cubic foot (natural gas is about 1000 BTU's per cubic foot). It is essentially free of sulphur compounds and nitrogen oxides. This gas can be substituted for natural gas at an existing facility.

Monsanto and Carborundum have also developed gas pyrolysis systems. Both approaches utilize air instead of pure oxygen as a source of oxygen. The heating value, 100 BTU's per cubic foot, is lower because of the dilution by the nitrogen in the air.

Methane and carbon dioxide can also be produced by decomposing solid waste in an anerobic (oxygen-free) environment. Programs are currently underway to recover methane produced both by the natural solid waste decomposition in a landfill and also from accelerated decomposition in a mechanical digester, similar to that employed in digesting sewage sludge.

In the sanitary landfill recovery program a well is drilled through the landfill and lined with perforated pipe. The gases are pumped out and then cleaned of the carbon dioxide using membrane filtration or cyrogenic separation techniques. The NRG NuFuel Company is currently installing gas recovery systems in landfills operated by the County of Los Angeles and the city of Phoenix. Both of these sites possess very specific characteristics which are necessary if the concept is to be feasible.

The National Science Foundation is currently supporting a research effort by the Dynatech Corporation to examine the feasibility of com-

bining solid waste with sewage sludge for digestion in a mechanical digestor. Pipeline quality gas would be recovered at the rate of 3,700 cubic feet of 900 BTU gas per ton of solid waste.

Lessons From St. Louis

The St. Louis demonstration has proved that the fundamental principle of operation, burning shredded solid waste in a tangentially fired utility boiler, is feasible. This is substantiated by both the committment of Union Electric to build a $70 million system and also by the Connecticut Resource Recovery Authority's decision to construct two shredded fuel plants. Several companies are offering to design, construct and operate similar systems.

The demonstration project in St. Louis is a research and development project. The system has not been optimized for continuous operation. In the next 12 months, EPA will spend approximately $1 million for process optimization and air pollution testing. The issues that will be examined by the process evaluation include:

Particle size - The nominal particle size of the shredded refuse is now 1.5 inches. Union Electric is tentatively planning to process to a smaller specification, 1.0 inch

Other system concepts call for a larger particle size. Obviously, there is little agreement on this issue. Particle size can effect combustion efficiency, air emissions, reliability of processing, and processing costs.

Redundancy - The processing system is one long chain of components. We've learned through experience that just about every link in the chain can fail at one time or another.

Further process evaluation can reduce the failure rate. Nonetheless, it appears that some redundancy will be necessary.

Handling and Preparation - Several problems have been encountered in the development phase of the project. Shredded waste has proved to be a difficult material to move in a pneumatic transport system. Solid waste is abrasive, bridges in storage bins, and stalls in the piping. None of these problems appear to be insurmountable. However, additional engineering work is needed.

Location of Classifier - This issue focuses primarily on whether the classifier should be placed between the shredders (assuming two shredders) or after both.

Type of Classifier - The St. Louis system utilizes an air classifier to separate the light fraction from the heavy fraction. Shredded waste is injected into a rising current of air. Several other air classifier concepts exist. Non-air classifiers, such as screens, are being proposed by some firms. The question of the necessity of one or two classifiers in series is also part of this issue.

Fire Control - The two fires at the St. Louis processing plant occurred during construction phases. Neither was associated with operational problems. Nevertheless, the combustible nature of solid waste must be kept in mind in designing a processing plant.

Utility Operation - Union Electric's experience with burning solid waste has been quite good. No increase in corrosion or erosion of the boiler tubes has been observed. The bottom ash handling is more difficult when solid waste is burned. It is necessary to flush the ash handling pit more often. This increase might be reduced by shredding the waste to a smaller nominal particle size. A lower firing rate might be another solution.

Height of Boiler Firing Ports - The height of the ports is another issue to be examined by further evaluation. The trade off between (a) better burnout and (b) increased air pollution (ash more likely to go out of stacks) from higher port placement is the major issue.

The second element of future EPA work will be further evaluation of the air emissions, the primary purpose being identification of techniques that can reduce particle emissions. These variables include particle size, location of boiler firing ports, boiler load, percentage of solid waste in the fuel mix, moisture content, the coal firing rate, and the operating conditions of the electrostatic precipitators (air pollution control device).

A preliminary analysis of the data from the EPA tests suggest that particulate emissions will be increased. The magnitude of the increase is not known because the effects of the variables identified in the previous paragraph are not known at this time. In contract, the data from the Union Electric tests indicate, as reported in the St. Louis Post-Dispatch, March 18, 1974, increases of 100 to 140 percent in particulate

emissions when firing solid waste with coal. This apparent discrepancy may be the result of differences in the experimental conditions or experiment techniques employed during the respective tests. EPA is presently trying to correlate these emissions data with the test variables to explain the differences in measured emission values.

Analysis of data on the gaseous emissions, which were measured only on the EPA test, indicate that the sulfur oxide (SOx) emissions are not appreciably changed by the firing of solid waste with coal, and that there are no significant changes in the emission levels of the following:

Hydrocarbons (HC)

Carbon Monoxide (CO)

Mercury Vapor (Hgv)

Chlorine (Cland HCT)

The air test evaluations are scheduled for the fall. It appears that the additional particulate emissions caused by burning waste will result in increased particulate emission control costs. The magnitude of the increase cannot be ascertained until the magnitude of the particulate level can be pinpointed.

In conclusion, although there are several issues that we will study more comprehensively, the basic concept of burning waste in a utility boiler has proved to be feasible. The major question in proving feasibility is the boiler corrosion and erosion issue. As stated previously, no boiler corrosion and erosion has been observed in the Union Electric facility. It appears that the other issues can be solved by further

engineering. This is substantiated by the commitment of many large companies to build second generation systems.

Status of Resource Recovery Implementations

We have recently inventoried the status of resource recovery implementations. The results are summarized in the following table.

Status of Recovery System Implementation*

May, 1974

Systems in Operation	Systems Selected	Communities Committed
5	11	17

The cities in each category are identified in Table I on the next page. The St. Louis, Missouri (600 ton per day) and Brockton, Massachusetts (600 ton per day) systems produce a shredded fuel product. The Nashville, Tennessee (700 ton per day) system produces steam and chilled water. The Franklin, Ohio system is a materials recovery system. No energy is recovered in Franklin although the pilot operation has led to the development of a second generation system that includes energy recovery. Browning-Ferris Industries operates a 500 ton per day materials recovery facility in Houston, Texas.

*Definitions:

Systems in Operation: Actual recovery from waste.

Systems Selected: Winner of RFP or construction contract announced.

Communities Committed: RFP issued, or design study underway, or construction funding has been made available, or community passed resolution.

Table I

DETAILED STATUS OF RECOVERY

SYSTEM IMPLEMENTATION

MAY 1974

Systems In Operation	Systems Selected	Communities Committed	Communities With Expressed Interest
St. Louis, Mo.	Baltimore, Md.	Wilmington, Del.	Albany, N.Y.
Franklin, Ohio	Lowell, Mass.	Chicago, Ill.	Dayton, Ohio
Brockton, Mass.	San Diego, Calif.	Monroe County, N.Y.	Providence, R.I.
Nashville, Tenn.	Charleston, W. Va.	Dade County, Fla.	Detroit, Mich.
Houston, Texas	Ames, Iowa	Milwaukee, Wis.	Denver, Colo.
	Saugus, Mass.	Memphis, Tenn.	Washington, D.C.
	Akron, Ohio	Cleveland, Ohio	Montgomery County, Md.
	Braintree, Mass.	New Orleans, Louis.	Erie County, N.Y.
	Bridgeport, Conn.	Boston, Mass.	Tidewater, Va.
	New Britain, Conn.	New York, N.Y.	Grand Rapids, Mich.
	Hempstead, N.Y.	Lane County, Ore.	Philadelphia, Penn.
		Minneapolis, Minn.	Cowlitz County, Wash.
		Hackensack, N.J.	
		Westchester County, N.Y.	
		Mt. Vernon, N.Y.	
		Knoxville, Tenn.	
		Housatonic Valley, Conn.	

Several states have developed programs to provide financing for resource recovery, either through grants or loans. Foremost of these is Connecticut's Resource Recovery Authority that has $250 in funds authorized. The authority will be repaid on a break-even basis through disposal fees. New York State has set aside $175 million of a $1.1 billion environmental bond for solid waste disposal facilities. The program will provide up to 50% of the capital costs. Other states with funding programs include Maryland, Rhode Island, Wisconsin, Washington, Minnesota, Illinois, and Tennessee.

Conclusions

As I have indicated, there is a tremendous amount of resource recovery activity in this country. In the past year, many cities and states have developed programs. Most are proceeding at a reasonable rate, addressing all the marketing, legal, financing, management, and technical issues through proper initial planning before issuing an RFP. However, some are not. Instead, they are rushing headlong into implementation without adequate planning.

This can be a dangerous oversight. Resource recovery has more in common with a for-profit business than a municipal service because products are produced that must be sold in the competitive marketplace. This element adds additional inherent risk. Consequently, I cannot overemphasize the importance of planning that will undoubtedly reduce the risks inherent in resource recovery because of this difference.

ENERGY CONSERVATION

THROUGH IMPROVED SOLID WASTE MANAGEMENT

By Robert A. Lowe

Office of Solid Waste Management Programs
U. S. Environmental Protection Agency

April, 1974

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ENERGY CONSERVATION

THROUGH IMPROVED SOLID WASTE MANAGEMENT

INTRODUCTION

Recent concern about energy supplies and environmental quality has focused attention on how resources are used and on the effects of resource use on the environment. Continued growth in the consumption of materials and the generation of wastes -- with their attendant use and waste of energy -- is neither inevitable nor necessary. Energy could be conserved by improving upon current materials use and waste management practices. This paper presents four opportunities to conserve energy through better solid waste management:

1.	Source Reduction	reducing consumption of products or reusing products, resulting in the use of less energy and materials and in the reduction in waste generation
2.	Energy Recovery	using solid waste as a fuel in place of coal, oil or gas
3.	Recycling	using recycled materials that consume less energy than virgin materials in manufacturing processes
4.	Improved Collection	using waste collection trucks more efficiently, reducing fuel consumption

Considered separately, the "maximum possible" energy savings from each of these four measures is:

	B/DOE* (thousand)	B/YOE** (million)	Btu's*** (trillion)
Source Reduction	115	42	244
Energy Recovery	393	143	832
Recycling	80	30	172
Improved collection	3	1	6

*B/DOE, barrels per day of oil equivalent
**B/YOE, barrels per year of oil equivalent
***Btu's, British thermal units. One trillion = 1×10^{12}

When considering the combination of these four energy conservation measures, the reader should be aware that the total energy benefits from improved solid waste management cannot be determined by adding the potential savings listed above. This is because the four areas are interrelated: energy saved in one area may reduce the potential for savings in another. For example, banning nonrefillable beverage containers (a source reduction measure) will reduce the amount of material available for recycling. Recycling combustible materials like paper will reduce the amount of waste available for energy recovery.

Some of the energy savings are additive. For example, energy recovery can be accompanied by the recycling of inorganic (noncombustible) materials. In fact, energy recovery improves the economics of materials

recycling. This occurs because an energy recovery system can usually be economically viable without materials recovery, although the opposite is not true. In an energy recovery system, the noncombustible recyclable materials are typically separated from the mixed waste (and therefore available for recycling) even if they are not going to be recycled. The additional cost of removing the recyclable materials appears to be less than the additional revenues from the sale of those materials.

In general, the largest quantity of energy is conserved by combining measures despite the reductions in certain categories. The potential energy savings from combining all measures in one possible scenario are:

	B/DOE* (thousand)	B/YOE (million)	Btu's (trillion)
Source Reduction	115	42	244
Energy Recovery	357	131	757
Recycling	46	17	98
Improved Collection	3	1	6
Total	521	191	1,105

*From Scenario 3 on Table 8 in the Summary
Note: See footnotes to Table 8.

Examples of the effects of certain energy conservation measures on other measures will be presented in the Energy Recovery and Recycling sections. An overview of the combined energy savings from

three possible energy conservation scenarios will be presented in the Summary.

To put these four energy conservation opportunities in perspective, they should be understood in the context of the flow of materials from acquisition of natural resources, through processing and manufacturing, to product use and waste disposal.

Existing methods of materials use and waste generation have two important consequences. First, a large portion (almost 50 percent) of the Nation's energy supply is consumed by the industrial sector. For example, fuel is consumed by the equipment that removes iron ore from the ground and transports the ore to the steel mill. Then energy is used to melt the ore and process it into steel. Next, energy is required for the equipment that transforms the steel into usable products in the manufacturing process. Finally, energy is consumed in the disposal operation (tractors on a landfill or in a resource recovery system). And all along, energy is consumed in transporting the material or product from each step to the next, including the final transport step: waste collection. Therefore, any reduction in the consumption of materials and products could conserve energy. The section on Source Reduction will discuss this further.

Secondly, conventional disposal methods--landfill or incineration without energy recovery--waste energy. A large portion of the materials discarded into the waste stream are combustible and can be converted

into energy, thereby conserving valuable fossil fuels. The waste stream also contains valuable materials--steel, aluminum, paper, glass--that can be recycled. Generally, although not in all cases, it takes less energy to manufacture a product from recycled materials than from virgin materials when all stages of materials acquisition, processing, manufacturing, and transportation are considered. To get a better appreciation for the opportunities for recovering energy and recycling materials, a closer look at the waste stream would be desirable.

The Waste Stream

EPA estimates that about 125 million tons of municipal wastes were generated from residential and commercial sources in the U.S. in 1971 (3.32 lbs/person/day).[1] Table 1 shows a breakdown of the waste stream, cross-referenced by material and by product. Product source categories are presented in millions (10^6) of tons on an "As Generated" basis. The materials in the waste stream are presented in millions of tons on both an "As Generated" and an "As Disposed"

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[1]This waste generation rate is lower than the widely quoted 190 million tons/year (5.3 lbs/capital/day) estimated in the 1968 National Survey of Community Solid Waste Practices. The National Survey was based on a sample of collected tonnage estimates (rather than systematic measurements) that were extrapolated to a national scale. These more recent estimates are primarily based on national material production and product marketing data. It is the judgement of EPA that these new figures are accurate to within approximately 25 percent and the 1968 survey over-estimated the national municipal solid waste stream.

TABLE 1

MUNCIPAL SOLID WASTE GENERATION
BY MATERIAL AND SOURCE, 1971

Kinds of Materials	Product Source Categories							Material Totals			
	Newspapers, books, and magazines	Containers and Packaging	Major household appliances	Furniture and furnishings	Clothing and footware	Food products	Other products	"As-Generated" Basis		"As Disposed" Basis	
								10^6 Tons	Percent	10^6 Tons	Percent
Paper	10.3	20.4	---	tr.	tr.	---	8.4	39.1	31.3	47.3	37.8
Glass	---	11.1	tr.	tr.	---	---	1.0	12.1	9.7	12.5	10.0
Metals	---	6.1	1.9	0.1	tr.	---	3.8	11.9	9.5	12.6	10.1
Ferrous	---	5.4	1.7	tr.	---	---	3.5	10.6	8.5		
Aluminum	---	0.6	0.1	tr.	---	---	0.1	0.8	0.6		
Other nonferrous	---	0.1	0.1	tr.	---	---	0.2	0.4	0.3		
Plastics	tr.	2.5	0.1	0.1	0.2	---	1.3	4.2	3.4	4.7	3.8
Rubber & leather	---	tr.		tr.	0.5	---	2.7	3.3	2.6	3.4	2.7
Textiles	tr.	tr.	---	0.6	0.5	---	0.7	1.8	1.4	2.0	1.6
Wood	---	1.8	---	2.3	tr.	---	0.5	4.6	3.7	4.6	3.7
Food Wastes	---	---	---	---	---	22.0	---	22.0	17.6	17.7	14.2
PRODUCT TOTALS	10.3	47.9	2.1	3.2	1.2	22.0	18.4	99.1	79.3	104.9	83.9
Yard Wastes								24.1	19.3	18.2	14.6
Misc. Inorganics								1.8	1.4	1.9	1.5
TOTAL WASTE								125.0	100.0	125.0	100.0
Percent Product Source Composition	8.2	33.5	1.7	2.6	1.0	17.6	14.7	---	79.3	---	83.9

basis. "As Generated" measures the weight of the material before it is mixed with other wastes. "As Disposed" measures the weight of the material after being mixed in trash cans and collection trucks. The difference between the two is the result of the migration of moisture from the wetter materials (food and yard wastes) to materials that absorb moisture (note the increase in the weight of paper) and to products to whose surface the moisture adheres (such as glass and metals).

The figures in Table 1 include wastes generated in household, commercial and business establishments and institutions (schools, hospitals, etc.) and excludes industrial process wastes, agricultural and animal wastes, abandoned automobiles, ashes, street sweepings, construction and demolition debris, and sewage sludges. The 125 million ton figure includes only those materials discarded into the waste stream and, therefore, excludes certain amounts of newsprint, corrugated and other materials that are already being recycled.

Large quantities of agricultural, forestry and industrial wastes and sewage sludge are generated each year. The amount of energy recoverable from these wastes may be significant; however, these wastes are not included in this analysis because the economic feasibility of recovering energy from them has not been determined.

The amount of products consumed and wastes generated has been growing at a rate estimated at 3 percent per year over the last decade. The population increased about 13 percent during the 1960's.

Although the population is growing slower now than in earlier years, the generation of wastes continues to increase.

These trends indicate a projected 3 to 4 percent annual increase in the amount of wastes generated in the years ahead. This means that more wastes will be available for energy recovery and materials recovery. More importantly, however, it means that the demand on supplies of natural resources will be greater and that more energy will be required to convert those resources into usable products. Thus, the need to conserve energy and to consume fewer products should become more apparent.

ENERGY CONSERVATION THROUGH SOURCE REDUCTION

Source reduction is defined as the reduction in the generation of solid waste through a reduction in the consumption of materials and products. There are four general approaches to achieve source reduction:

1. Product reuse (e.g., returnable bottles)
2. Reduce resource intensiveness (e.g., smaller autos)
3. Increased product lifetime (e.g., longer lasting household appliances)
4. Decreased product consumption (e.g., reduced packaging consumption)

Table 1 indicates some of the broad product categories in the waste stream that could be impacted by source reduction measures.

Almost invariably, any source reduction action will result in the conservation of energy. Although the energy conservation impacts of most of the many possible source reduction actions have not been quantified, an estimate was made of the potential energy savings resulting from a reduction in one product category, packaging, to put the energy conservation potential of source reduction in perspective. If per capita packaging consumption in 1972 were reduced to the levels that existed in 1958, over 560 trillion Btu's could have been saved in 1972, the equivalent of 267,000 B/DOE (Appendix I).

Another source reduction measure, affecting a portion of the packaging category, is the substitution of refillable (returnable) beverage containers for nonrefillable (one-way) containers. Using a refillable container saves at least half of the energy required to use a nonrefillable bottle or can. If all beverages were shipped in refillable bottles in 1972 (and each bottle were used 10 times and returned to the bottler in "piggy back" fashion on the return trips of the consumer's automobile and the distributor's truck), about 244 trillion Btu's or 115,000 B/DOE could have been conserved.

It is significant to note that per capita consumption of materials has grown considerably in recent years. Consumption of packaging materials, for example, has grown at a rate of 2.8 percent per person per year for the last 13 years. Based upon projected growth rates, the energy that could be saved by returning to 1958 per capita packaging consumption rates will be twice as large (1,174 trillion Btu's, or 555,000 B/DOE) in 1980 as in 1972.

The consumption of beverage containers has also grown, and continues to grow, faster than population growth and the consumption of beverages. For example, while the consumption of beer and soft drinks rose 29 percent between 1959 and 1969, the consumption of beer and soft drink containers rose 164 percent. Based upon projected trends continuing toward use of nonrefillable beverage containers, if all consumers in 1980 use refillable bottles (and these bottles are used 10 times), about 421 trillion Btu's (70 percent more than the potential savings estimated for 1972) or about 198,000 B/DOE could be saved.

ENERGY RECOVERY FROM WASTE

Theoretical Energy Potential

About 70 to 80 percent of residential and commercial wastes is combustible with an energy content of about 9 million Btu's per ton. Theoretically, if all solid waste in the U.S. had been converted into energy in 1971, about 1.1 quadrillion (1.1×10^{15}) Btu's per year would have been generated. This is the equivalent of over 522,000 B/DOE, or 190 million B/YOE. The growth in population and per capita waste generation would cause these figures to increase to 1,440 trillion Btu's per year by 1980, or about 680,000 B/DOE or 248 million B/YOE. These and other findings are summarized on Table 2. (Appendix II)

Available Energy Potential

Not all waste is available for energy recovery. Energy recovery systems require large quantities (at least 200 to 250 tons per day) of waste delivered for processing at one site in order to achieve economies of scale. For this reason, energy recovery appears feasible only in more densely populated areas, such as Standard Metropolitan Statistical Areas (SMSA's). If energy recovery had been practiced in all SMSA's in 1971, over 832 trillion (832×10^{12}) Btu's would have been recovered. This is equal to over 393,000 B/DOE, or 143 million B/YOE. By 1980, the energy potentially recoverable from the SMSA waste stream is projected to be about 1,085 trillion Btu's per year, the equivalent of over 512,000 B/DOE, or 187 million B/YOE.

TABLE 2

ENERGY POTENTIALLY RECOVERABLE FROM WASTE

	1971			1980		
	Btu's* (trillion)	B/DOE** (thousand)	B/YOE*** (million)	Btu's (trillion)	B/DOE (thousand)	B/YOE (million)
Theoretical	1,106	522	191	1,440	680	248
Available	832	393	143	1,085	512	187
Projected Implementations	-	-	-	85	40	15
Potential Candidates	-	-	-	558	263	96

*Btu: British Thermal Unit

**B/DOE: Barrels per day of oil equivalent. (Assuming 5.8 million Btu's per barrel of oil and 365 days per year.)

***B/YOE: Barrels per year of oil equivalent.

Using solid waste as an energy source offers several distinct benefits:

1. Replaces the use of fossil fuels.
2. Produces low sulfur oxide emissions because solid waste has a low sulfur content.
3. Reduces the amount of land needed for disposal sites.
4. Is a readily available, growing--rather than depleting --domestic source of energy.

Projected Implementations of Energy Recovery Systems

At the present time, energy is being recovered from post-consumer solid waste in only one location in the U.S.: in St. Louis, Missouri at an EPA-supported demonstration plant operated by the City of St. Louis and the Union Electric Company.

Interest in energy recovery is increasing across the country. Several more systems (including another Federally supported demonstration plant) will be operating before the end of 1975. About 40 additional communities are seriously considering the recovery of energy from waste.

Based on energy recovery projects existing or planned at the present time, it is projected that by 1980 almost 30 cities and counties around the country should be operating the equivalent of about thirty-six 1,000 ton-per-day plants, recovering an estimated 85 trillion Btu's per year, or 40,000 B/DOE, or 15 million B/YOE.

A list of communities where energy recovery systems are underway or planned is included in Table 3. This list represents those communities that have already taken definite steps (by conducting a feasibility study, by vote of the county legislative body, or by some similar step) towards implementation of an energy recovery system. However, there are many other cities that are potential candidates for energy recovery systems.

TABLE 3

PROJECTED IMPLEMENTATIONS OF ENERGY RECOVERY SYSTEMS BY 1980

State	City	Tons of Solid Waste Per Day (1980)
California	San Diego	200
Connecticut	Bridgeport	1,200
District of Columbia	Washington	1,000
Illinois	Chicago	2,000
	Chicago area, outside city	1,000
Iowa	Ames	200
Maryland	Baltimore	1,000
	Montgomery County	1,200
Massachusetts	Braintree	240
	East Bridgewater (near Brockton)	1,200
	Lawrence	1,000
	Saugus (near Boston)	1,200
Missouri	St. Louis	8,000
New Jersey	Essex County (Newark area)	1,000
	Hackensack Meadowlands	2,000
	Union County (Elizabeth) or Middlesex County (New Brunswick)	1,000
New York	Albany	500
	Hempstead, L.I.	1,000
	Monroe County (Rochester)	500
	New York City	2,000
	Westchester County (White Plains)	1,500
Ohio	Akron	1,000
	Cleveland	500

TABLE 3, Continued

State	City	Tons of Solid Waste Per Day
Oregon	Eugene	700
Pennsylvania	Philadelphia	2,400
Puerto Rico	San Juan	1,000
Tennessee	Knoxville	500
	Memphis	500
	Nashville	750
	Total Tons Per Day in 1980	36,290
	Number of equivalent 1000 tons per day plants	36
	Energy recoverable in 1980	85 trillion Btu's per year
		40,000 barrels per day of oil equivalent
		15 million barrels per year of oil equivalent

Potential Candidates: Areas Where Local Conditions Favor Energy Recovery

In some areas, there are certain local conditions that favor the implementation of energy recovery systems. These include:

1. Economics - where disposal costs are high because inexpensive close-by land is not available or because alternative fuel costs are high.

2. Markets - where local market conditions exist to take advantage of available technology. These conditions include a boiler suitable for burning waste or a network for distributing steam for heating downtown buildings.

3. Public Interest - where public officials are likely to select energy recovery over other options because of the popularity among their constituents of energy recovery as an environmental or energy issue.

Using these local conditions as screening criteria, EPA has identified 48 SMSA's as potential candidates for energy recovery. These 48 SMSA's are metropolitan areas that include at least 100 to 150 separate county or city governmental units. A list of these SMSA's is included in Table 4. These are the areas where energy recovery could be feasible by 1980, while the previous list (Table 3) indicated recovery systems that are expected to be implemented. The distinction between the two lists is the difference between actual implementations and opportunities for implementation. The energy recoverable from all the residential and commercial waste in these 48 areas in 1980 would be equal to over 263,000 B/DOE, or 96 million B/YOE.

TABLE 4

POTENTIAL CANDIDATE AREAS (SMSA's)
FOR ENERGY RECOVERY IN 1974
with potential energy recoverable projected to 1980

Note: Recoverable energy is a function of waste generation, which is a function of population

	Standard Metropolitan Statistical Areas	Population 1970 (thousands)
1.	New York, New York	11,572
2.	Chicago, Illinois	6,979
3.	Philadelphia, Pennsylvania	4,818
4.	Detroit, Michigan	4,200
5.	Washington, D.C. - Md. - Va.	2,861
6.	Boston, Massachusetts	2,754
7.	Pittsburgh, Pennsylvania	2,401
8.	St. Louis, Missouri	2,363
9.	Baltimore, Maryland	2,071
10.	Cleveland, Ohio	2,064
11.	Newark, New Jersey	1,857
12.	Minneapolis - St. Paul, Minnesota	1,814
13.	Milwaukee, Wisconsin	1,404
14.	Atlanta, Georgia	1,390
15.	Cincinnati, Ohio	1,385
16.	Patterson, New Jersey	1,359
17.	San Diego, California	1,358
18.	Buffalo, New York	1,349
19.	Miami, Florida	1,268
20.	Denver, Colorado	1,228
21.	Portland, Oregon	1,009
22.	Columbus, Ohio	916
23.	Providence, Rhode Island	911
24.	Rochester, New York	883
25.	San Antonio, Texas	864
26.	Louisville, Kentucky	827
27.	Memphis, Tennessee	770
28.	Albany, New York	722
29.	Toledo, Ohio	693
30.	Akron, Ohio	679
31.	Hartford, Connecticut	664
32.	Gary, Indiana	633
33.	Jersey City, New Jersey	609
34.	Nashville, Tennessee	541
35.	Jacksonville, Florida	529
36.	Wilmington, Delaware	499
37.	Knoxville, Tennessee	400

TABLE , Continued

38.	Bridgeport, Connecticut	389
39.	New Haven, Connecticut	356
40.	Peoria, Illinois	342
41.	Little Rock, Arkansas	323
42.	Chattanooga, Tennessee	305
43.	Madison, Wisconsin	290
44.	Rockford, Illinois	272
45.	Lawrence, Massachusetts	232
46.	Charleston, West Virginia	230
47.	Eugene, Oregon	213
48.	Brockton, Massachusetts	190
	Total population, 1970	71,786
	Total population, 1980	78,462
	Waste generation, 1980 (annual)	62.0 million tons
	(daily)	170 thousand tons
	Number of equivalent 1000 TPD plants	170
	Energy recoverable	558 trillion Btu's per year
		263,000 barrels per day of oil equivalent
		96 million barrels per year of oil equivalent

Energy Recovery Products

Solid waste can be used as or converted into any of five individual energy products (Reference 1):

1. Steam
2. Solid fuel
3. Liquid fuel
4. Gaseous fuel
5. Electricity

To aid in conceptualizing the state of the art of energy recovery, this section presents these five energy products and distinguishes them from one another at the point of sale. This distinction is made because the selection of an energy recovery system will be made primarily on the basis of marketing considerations; that is, the system will be designed so that its products will be accepted by the potential customers in the market.

Two of the five products--steam and electricity--are end-products. Steam is also an intermediate product when it is used to generate electricity. Solid, liquid and gaseous fuels are raw materials that can be burned to produce either end-product, steam or electricity. These fuels can come either from fossil resources (coal, oil or gas) or from solid waste (shredded/classified waste-fuel, or pyrolysis oil

or gas). Therefore, solid waste can be a source of energy, whether it is sold as steam, fuel or electricity.

Steam

By burning solid waste in a water wall incinerator, steam can be generated for use in (1) heating and cooling buildings (district heating and cooling) and (2) industrial manufacturing.

Technically, steam recovery is the best-developed method for recovering the energy value in solid waste. But marketing steam is often a difficult task because (1) steam is not storable and (2) can be transported only over very short distances. Nevertheless, many cities have steam distribution networks already established.

The Nashville (Tennessee) Thermal Transfer Corporation, a private non-profit corporation, will soon begin full scale operation of a facility to produce steam and chilled water for heating and cooling downtown buildings. The energy will be provided by a water wall incinerator fueled entirely (except for emergency situations) by solid waste. Steam and chilled water will be sold at prices that result in substantial savings to customers. At the same time, the revenues from these sales will pay for all capital and operating costs, including underground distribution lines. Moreover, the City will be able to dump its waste at the plant at no charge. (The City is responsible for disposing of the residue.)

Rather than build a new water wall incinerator to produce and sell steam, it may be more economical to sell the waste as a fuel to supplement the fossil fuels used in existing steam generating boilers.

Solid Fuel

Solid waste can be sold in solid form as a substitute for conventional fossil fuels in existing or newly designed combustion units. The major markets for solid waste fuel are (1) utility boilers (2) industrial steam and steam-electric boilers, and (3) district heating and cooling facilities (i.e., heating downtown buildings).

The largest and most readily available boilers are electric utility boilers. Because most of these boilers are suspension fired (the fuel burns in mid-air in a residence time of one or two seconds), the pieces of solid waste fuel must be reduced in size (by shredding, milling or pulping) so that they can be burned in the boilers' short residence time. Burning prepared solid waste as a supplement to coal in an existing utility boiler has been demonstrated in St. Louis, Missouri. This system is described in Energy Recovery from Waste. (Reference 2)

The prerequisite for this application is that the boilers must be capable of handling ash--both bottom ash and fly ash. All boilers designed to burn coal have ash handling equipment. Although many coal-burning boilers were subsequently retrofitted to burn oil or gas, the ash handling equipment is still operable in most cases. Where the Boilers Are: A Survey of Electric Utility Boilers with Potential Capacity for Burning Solid Waste as a Fuel (Reference 3) describes the location, design characteristics and the refuse-burning capacity of most of the utility boilers in the U.S. capable of burning solid waste.

Oil and Gas through Pyrolysis

To enable solid waste to be used in boilers that do not have ash-handling capabilities, the solid waste can be converted into a combustible liquid or gas using a process known as pyrolysis.

Pyrolysis is the thermal degradation of organic substances in an oxygen deficient atmosphere. The concept is under development by nearly a dozen different private and public organizations. The primary motivation is to develop a system wherein solid waste can be converted into a storable, transportable fuel--either liquid or gas. Once this is done, many of the constraints that limit the marketability of solid waste as a fuel are minimized.

At this time, several pyrolysis systems have been demonstrated at the pilot plant level, 4 to 150 tons per day, but no full-scale systems are operational. Several plants will be operational within the next year or two. Monsanto Enviro-Chem Systems, Inc. is building a 1,000 ton per day gas pyrolysis plant in Baltimore, Maryland with EPA support. Union Carbide Corporation is building a 200 ton per day gas pyrolysis plant in South Charleston, West Virginia. And Garrett Research & Development Corporation is building a 200 ton per day oil pyrolysis plant in San Diego County, California, also with EPA support. By 1980, sufficient experience should be gained to make this a viable option for widespread implementation.

Gas: Methane Recovered from Landfills

Gases are produced in land disposal sites as a result of the microbiological decomposition of the organic matter (such as food, paper and yard wastes) placed in the landfill. One of these gases is methane, a combustible gas that is the main component of natural gas. These gases can be recovered and used either as a fuel in engines designed to run on methane or, after treatment to remove impurities, as a substitute for natural gas in conventional commercial pipelines.

At the present time, methane is being recovered at only one site: a pilot plant operated by the Los Angeles Power and Water Company on the City of Los Angeles' Sheldon-Arleta Landfill. Plans are already underway to expand this facility and another.

Methane recovery utilizes available technology, but there are still several unknowns. The most important unknown is the length of time that landfills will produce methane. Nevertheless, the economics of this energy recovery option are becoming more favorable as the value of natural gas increases.

Electricity

Instead of selling prepared waste as a solid fuel, solid waste can be converted into electricity; and then the electricity can be sold. There are two ways of doing this: steam-electric boilers and gas turbines. These two options have significant shortcomings at the present time.

The economics of steam-electric boilers are most favorable when they are large enough to have economies of scale and when the heating value per unit of volume of the fuel is high (and thus less boiler area is required for combustion). Steam-electric boilers designed to burn only solid waste appear to be less economical than boilers designed to burn waste in combination with fossil fuels because (1) the heating value of waste fuel per unit of boiler combustion area is lower than fossil fuels and (2) the amount of waste that can be delivered economically to one site is far lower than fossil fuels. Gas turbines using solid waste as an energy source are encountering technical difficulties. Therefore, at the present time, selling electricity produced from waste appears to be an option that is less advanced than those discussed above.

Effect of Paper Recycling on Energy Recovery

Waste paper can be recycled as a fiber source; or it can be converted to energy. (Recycled paper can be converted to energy at a later time.) At the time of disposal, these options--recycling or energy recovery--are mutually exclusive. Obviously, the effect of removing paper from the waste stream is important in the management and design of an energy recovery system.

Paper can be removed from the waste stream in several ways:

1.	Source separation:	separating paper at the home or factory for recycling before it is mixed with other wastes during the collection process
2.	Hand picking:	removal of bundled paper from the mixed waste
3.	Mechanical separation:	removal of paper fiber by mechanically processing the mixed waste stream

Only certain types of paper products can be segregated at the source and collected economically for recovery. (Reference 4) These grades of paper, which account for about 47 percent of all the paper in the waste stream are:

1. Newspapers from residential sources,
2. Corrugated from commercial and industrial sources, and
3. Mixed office papers

It is estimated that 40 to 60 percent [2] of this paper could realistically be recovered. Expressed as a percentage of all the paper in the waste stream, this represents a recovery rate of about 27 percent.

[2]Available paper excludes the paper presently being recycled; recovery percentages would be higher if presently recycled paper were included.

Table 5 shows the effect on the heating (energy) value of the waste stream at various rates of recovery through source separation of the available paper grades (newsprint, corrugated and mixed office papers).

TABLE 5

EFFECT OF SOURCE SEPARATION

of Newspaper, Corrugated and Mixed office papers

Recovery Rate (percent of all paper)	Reduction in Heating Value of the Waste Stream (percent)
0%	0%
15	4
27	7
35	9

If energy recovery had been practiced in all SMSA's in 1972 simultaneously with a 35 percent rate of source separation and recycling of paper, the amount of energy recoverable from waste would have been reduced about 9 percent, from 393,000 B/DOE to 357,000 B/DOE. The energy consequences of producing paper from recycled fiber will be discussed in the following section.

ENERGY CONSERVATION THROUGH RECYCLING

Recycling generally conserves energy: when two production systems are compared--one using virgin materials and the other using recycled (secondary) materials--the system using recycled materials most often consumes less energy when all stages of materials acquisition, processing and transportation are included.

The technical feasibility of recovering materials from the municipal waste stream has been demonstrated. Had currently-known technology been applied in 1972 to residential and commercial solid wastes in metropolitan areas, almost 14 million tons of steel, aluminum and glass could potentially have been recovered and substituted for their virgin material counterparts.

Such a substitution, based on preliminary estimates, (Appendix III) would have yielded a national primary energy saving of about 172 trillion Btu's per year in 1972, or the equivalent of 80,000 B/DOE. Moreover, the potential energy savings from recycling in the future is expected to grow in proportion to projected increases in the consumption of recyclable materials. (Table 6)

In the area of paper recycling, using recycled fiber in the paper and paperboard production systems appears to require less energy than using virgin woodpulp. However, no estimates of the potential energy savings have been presented in this analysis for three reasons. First, independently developed estimates on the energy effects of paper

TABLE 6

NATIONAL ENERGY SAVINGS FROM MAXIMUM POSSIBLE RECYCLING OF ALUMINUM, FERROUS, AND GLASS FRACTIONS OF POST-CONSUMER SOLID WASTE [TRILLIONS OF BTU'S]*

Materials**	1972	1975	1980	1985	1990
Aluminum [46-56%]	82	115	164	212	274
Ferrous [63-67%]	81	87	95	107	116
Glass [50-52%]	8	13	15	16	16
Total Energy	172	215	274	335	406

*Energy savings are based on "total system" analyses which include primary energy required for raw material acquisition and electricity input as well as for principal refining processes.

**Figures in brackets indicate percentages of the individual material in nation-wide solid waste assumed to be recoverable from a "maximum possible" recovery effort. Lower percentages are for earlier years, higher percentages for later years when larger proportions of popula- is expected to reside in SMSA's and when extraction efficiency expected to rise. Recovery quantities based on residential and commercial solid waste only.

recycling differ materially in certain significant quantitative details. Until these estimates are systematically and thoroughly compared and reconciled, meaningful data are not available. Secondly, the more energy intensive virgin pulping operation typically derive at least part of their energy requirements from bark and other wood wastes rather than from fossil fuel sources. In some cases, by-product energy derived from spent pulping liquors is sufficient to supply all of or more than the pulping energy requirements. Thirdly, a satisfactory definition of the "maximum possible" paper recycling scenario has not been developed, mainly because there are a great many variables on both the supply and demand sides of the waste paper utilization picture. Unlike the other three waste materials previously estimated (aluminum, ferrous, and glass) the potential incremental supply of post-consumer waste fiber supply would be not only a very large fraction of total national fiber consumption, it could also be directed (from a technical standpoint) into an almost infinite variety of product use patterns.

Effect of Source Reduction on Recycling

It was mentioned earlier that implementation of one energy conservation measure may reduce the benefits from another. One example of this is the effect of source reduction on the potential energy savings from recycling. Because source reduction will decrease the amount of materials available for recycling, the potential energy savings resulting from recycling will also be reduced by source reduction. Therefore, the energy savings from

source reduction of recyclable materials and the energy savings from recycling are not additive.

However, based on estimates involving beverage containers, the energy savings from source reduction appear to be greater than the energy savings from recycling. For example, as was noted earlier, if all consumers had used only refillable bottles in 1972, about 244 trillion Btu's or 115,000 B/DOE could have been saved because of source reduction.

But this source reduction action would have removed about 6.2 million tons of material from the waste stream that could have been recycled. This assumes that steel and aluminum beverage cans would not have been used because they cannot be refilled; it also assumes that refillable bottles would make 10 "trips" (the original and 9 successive fillings). The effect on materials used, in millions of tons, would have been as follows:

Beverage Container Materials Used in 1972		Beverage Container Materials Used in an All-returnable System	Beverage Container Materials Removed from the Waste Stream
Aluminum	.5	-	.5
Steel	2.0	-	2.0
Glass	6.2	2.5	3.7
	8.7	2.5	6.2

If these 6.2 million tons of materials had not been available for recycling in 1972 because of an all-refillable bottle program, the effect on Table 6 above would have been as follows:

Materials	Energy Savings from Maximum Possible Recycling 1972 (trillion Btu's)	Energy Savings "Lost" because of use of Refillable Bottles-1972 (trillion Btu's)	Energy Savings from Recycling when only Refillable Bottles are used 1972 (trillion Btu's)
Aluminum	82	55	27
Ferrous	81	16	65
Glass	8	2	6
	172	73	98

Thus, if an all-refillable bottle program were in effect in 1972, 250 trillion Btu's could have been saved because of source reduction, but the energy savings from recycling would have been reduced by 73 trillion Btu's. In terms of barrels per day of oil equivalent, 115,000 B/DOE could be saved because of this source reduction measure, while the potential savings from recycling would be reduced by 34,000 B/DOE (from 80,000 B/DOE to 46,000 B/DOE).

ENERGY CONSERVATION THROUGH IMPROVED COLLECTION

The preceding sections focused on the energy conservation impacts associated with producing and recycling the waste materials themselves. An additional energy conservation opportunity is associated with the collection of solid waste. Solid waste collection is highly dependent on fuel, but there are several short and long range steps which can be taken to conserve energy (Reference 5).

Background

Solid waste collection and land disposal consume 287 million gallons of gasoline and 326 million gallons of diesel fuel per year. Of these figures, collection operations consume approximately all of the gasoline and half of the diesel fuel. Almost three-quarters of the fuel used for solid waste collection is consumed in residential collection.

Use of diesel fuel for solid waste collection and disposal is about 3.6 percent of all highway use of diesel fuel. Use of gasoline for solid waste collection is about 1.6 percent of all truck use of gasoline.

Energy Conservation Measures

The following short range steps could be taken to reduce energy requirements for residential solid waste collection:

1. If communities that presently collect solid waste twice a week were to collect only once a week, those communities could save 29 percent of the fuel used for collection.
2. Communities with separate collection of food waste could essentially halve their fuel requirements by collecting all wastes at once. However, separate collection of newspaper and other materials for resource recovery should be encouraged because the energy saved in the recycling process typically offsets the additional fuel required for collection.
3. A savings of 5 percent could be made in those communities which have poor routing.
4. Other short term changes include:
   a. Improved storage practices
   b. Conversion from backyard to curbside pick-up
   c. Minimizing separate pick-ups for bulky items
   d. Placing waste in clusters or on one side of the street
   e. Reducing street sweeping operations

Long term actions include use of transfer stations where warranted, use of better and properly sized collection equipment, elimination of situations where several private collectors operate on the same street, and location of disposal sites nearer to population centers.

Impact

On a national basis, it is estimated that 18.2 million gallons of diesel fuel and 39.1 million gallons of gasoline per year would have been saved by changing from twice-a-week to once-a-week collections (excluding inner-city areas) and by using better routing patterns for collection. This is based on levels of service and equipment utilization in the 1972-1973 time period. This savings is the equivalent of 3,000 B/DOE.

SUMMARY

The energy conservation measures described above could be combined in a variety of ways. Table 8 presents the "maximum feasible" energy conservation benefits from three sample scenarios. Note that energy recovery and recycling of noncombustible materials are compatible. Note also in Scenario 2 that, when paper is recycled, the overall fossil fuel conservation potential is reduced; however, there are resource conservation and other environmental impacts associated with recycling paper that may offset a reduction, if any, in potential energy savings. And note that the combination of source reduction and recycling (Scenario 3) offers a larger potential energy savings than either option by itself.

Of the three scenarios depicted in Table 8, Scenario 3 offers the greatest potential benefits, 521,000 B/DOE. This is a significant quantity of energy. By comparison, 521,000 B/DOE is equal to:

7 percent of all the fuel consumed by utilities in 1970 (7.1 million B/DOE

14 percent of all the coal consumed by utilities in 1970 (3.7 million B/DOE)

35 percent of the oil projected to be delivered through the Alaskan Pipe Line (1.5 million B/DOE)

52 percent of the crude oil imported directly from the Middle East in Sept., 1973 (1.0 million B/DOE)

1.5 percent of all energy consumed in the U.S. in 1970 (32.5 million B/DOE)

Table 8

Combined Energy Savings from Three "Maximum Possible" Energy Conservation Scenarios for 1972 (thousand barrels per day of oil equivalent)

	Scenario 1	Scenario 2	Scenario 3
	Energy Recovery Recycling and Improved Collection	Energy Recovery Recycling, Improved Collection and Source Separation	Energy Recovery, Paper and Materials Recycling, Improved Collection and Source Reduction
Energy Recovery	393	357[1]	357[1]
Recycling[2]	80	80	46
Improved Collection	3	3	3
Source Separation[3]	-	N.A.	N.A.
Source Reduction[4]	-	-	115
Total	476	440	521

[1]Energy content of wastes reduced 9 percent by source separation. See note 3.

[2]Recycling of noncombustible materials: aluminum, glass and steel.

[3]Source separation and recycling of newsprint, corrugated and mixed office waste papers at a recovery rate of 35 percent of the paper in the waste stream.

[4]Source reduction refers to the beverage container example described above: it assumes that all consumers used refillable bottles and that each bottle made 10 trips.

N.A. - Data on the energy savings from recycling paper are not available. See page 28.

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APPENDICES

I National Energy Savings from Source Reduction--Packaging: An Estimate of Possible Impact, by Michael Loube

II Methodology for Determining the Amount of Energy Potentially Recoverable from Waste, by Robert A. Lowe

III National Energy Savings from Materials Recycling: Some "Maximum Possible" Estimates for Ferrous Metals, Aluminum and Glass, by Frank A. Smith

APPENDIX I

NATIONAL ENERGY SAVINGS FROM SOURCE REDUCTION - PACKAGING: AN ESTIMATE OF POSSIBLE IMPACT

by Michael Loube

Introduction

Source reduction is defined as the reduction in consumption of materials and products which also results in a reduction in the generation of wastes. The source reduction concept has grown out of the thesis that solid waste is an effluent theoretically easier to reduce than dispose. Almost by definition most source reduction actions will result in energy savings.

There are four major technical approaches that can be used to achieve source reduction. They are: 1) reuse of products, 2) reduced resource intensity of products, 3) increased lifetime of products, and 4) decreased consumption of products. The energy savings in the packaging sector described in this paper concern two of these approaches. First, there is an analysis of the energy savings arising from the reuse of the beverage (beer and soft drink) container portion of packaging materials. Secondly there is an analysis of the energy savings achieved if the consumption of all packaging materials (other than beverage containers) could be reduced.

Findings

1. Reuse of Beverage Containers

A source reduction program tailored toward the reuse of beer and soft drink containers (Tables 1-2) will produce a substantial reduction in total energy required for the consumption of beverages. A shift from the current mix of one-way and refillable beverage containers to a system of all refillable containers (the average container being used ten times) would have saved in 1972 a total of 244 trillion Btu's. This potential energy savings is equivalent to about 115,000 barrels of oil, or slightly more than .3% of the nation's total primary energy (fossil fuels plus hydroelectric plus nuclear). By 1980, given the anticipated growth in beverage consumption and shifts between container types, the annual savings that would be generated from a switch to an all refillable system would have increased to approximately 421 trillion Btu's (about 200,000 barrels of oil per day).

2. Reduced Consumption of Packaging (Excluding Beverage Containers)

The energy savings achievable from a source reduction measure that would reduce the consumption of packaging (other than beverage containers) were also estimated (Table 3). Since packaging must protect the product an attempt was made to set as a maximum reduction only the removal of "excess" packaging. This was estimated by identifying the maximum reduction possible as equivalent to 1958 packaging consumption (i.e., the percentage of each material used in packaging in 1958 was assumed to remain constant). Economic growth and increased product consumption since 1958 was then estimated (equal to the increase in non-durable goods purchased) and total packaging consumption was increased to derive a goal for reduced packaging.

The potential energy savings from reduced packaging (excluding beverage containers) would have been, in 1971, 322 trillion Btu's. This savings is equivalent to about 150,000 barrels of oil per day or about .5% of the nation's total primary energy. By 1980, the annual savings that would be generated by decreased packaging consumption would have increased to 753 trillion Btu's (about 356,000 barrels of oil per day).

3. Energy Savings, all packaging materials

These two source reduction measures (reuse of beverage containers, and reduced packaging consumption) are additive (Table 4). Therefore the total energy savings potentially available in the packaging area are:

1) In 1971, 566 trillion Btu's (equivalent to 267,000 barrels of oil per day, or 18% of total primary energy)

2) In 1980, 1174 trillion Btu's (equivalent to 555,000 barrels of oil per day, or 1.7% of present total primary energy demand)

4. Alternative Energy Saving Mechanisms

While source reduction measures designed to reduce or reuse packaging materials provide substantial energy savings, they do impact other potential resource recovery mechanisms. The potential impact on three resource recovery techniques is discussed

below. Impacts are identified for: 1) Separate Collection, 2) Materials Recovery Systems, and 3) Energy Recovery Systems.

A. Separate Collection - Most separate collection activity currently centers on newspapers being segragated by the householder. Source reduction of packaging materials would have no impact on this activity.

A few cities have tried (mostly unsuccessfully) to collect bottles and cans separately. Reuse of beverage containers would probably eliminate the need and potential economic viability of this activity.

Separate collection of corrugated boxes (a packaging material) is practiced (and currently increasing) by some commercial establishments. Since source reduction would probably be accomplished by changing the design of this packaging material in such a way as to use less material or to be reusable, or both, source reduction and separate collection of corrugated packaging could be complementary activities. Both are aimed toward reducing the ultimate waste disposal of packaging materials.

B. Materials Recovery Systems - Few municipal materials recovery systems are currently in existence, but numerous cities are examining their potential (either by themselves or in conjunction with energy recovery systems). If these systems had operated in all metropolitan areas in 1972, the energy saved by recycling the aluminum, glass, and ferrous portions of post-consumer solid waste would have been 172 trillion Btu's (or the equivalent of about 80,000 barrels of oil per day). A source reduction measure designed to reuse beverage containers while saving 244 trillion Btu's would reduce the potential savings from materials recovery (Table 5) by 73 trillion Btu's.

Therefore, material recovery by itself could save 172 trillion Btu's; source reduction of beverage containers by itself could save 244 trillion Btu's. Combined, the two measures would save 343 trillion Btu's as follows:

Energy Savings from Recycling and Source Reduction Combined

Energy savings from recycling alone	172
less: energy savings "lost" when recycling and source reduction measures are combined	73
Net savings from recycling	99

plus: energy savings from source reduction (refillable bottle program)	244
Total savings from Combined Measures	343

This analysis assumes that the glass remaining in the waste stream with a refillable beverage container system would not be easier to recover for recycling than it is now. This would probably not be true since most glass bottles (even though not refillable because of cracks or chips) would be returned to the supermarket or bottler. The glass bottle waste stream would no doubt be substantially segregated from the general waste stream and therefore easier to recover.

However the effect on energy savings would be small. An additional 0.7 trillion Btu's would be saved (assuming glass recovery efficiency would increase from 50% for normal municipal recovery to 70% for recovery from a segregated glass bottle waste stream).

C. Energy Recovery Systems - Few municipal energy recovery systems are currently in existence, but numerous cities are examining their potential. If these systems had operated in all metropolitan areas in 1972, the energy available for use would have been about 832 trillion Btu's.

Source reduction of packaging materials would remove some of the organic (combustible) materials from the waste stream. This would result in a reduction in the energy available to energy recovery systems in the amount of 82.4 trillion Btu's (Table 6). Energy recovery by itself could save 832 trillion Btu's (see Table 2 in the text); removing combustible materials by source reduction would reduce the energy recovery potential by 82 trillion Btu's to 750 trillion Btu's. However, this 750 trillion Btu savings would be added to the 322 trillion Btu saving attributable to source reduction, for a combined savings of 1,072 trillion Btu's.

5. Net Source Reduction Savings

The total potential energy savings from source reduction of packaging materials including beverage containers would amount to about 566 trillion Btu's in 1972. Various combinations of source reduction approaches, materials recovery and energy recovery systems would provide increased energy savings (Table 7). If all three systems were in existence in 1972, the energy saved would have amounted to 1,415 trillion Btu's.

TABLE 1

Energy Savings of Source Reduction Program-
Reusable Beer and Soft Drink Containers

(1972)

Container Type	Beverage Delivered (Million Oz.)[1]		Energy Required Per Million Oz. (million Btu's)[2]	Energy Consumed (trillion Btu's)		Energy Saving of All Returnable System (trillion Btu's)
	Present System	All Returnable System		Present System	All Returnable System	
Returnable Glass Bottle	293,554	1,007,654	184	54	186	(132)
One Way Glass Bottle	260,989	-	550	144	-	144
Aluminum Can	104,336	-	747	78	-	78
Bi-Metal (Steel) Can	348,775	-	443	154	-	154
Total	1,007,654	1,007,654		430	186	244

1. Midwest Research Institute, Draft Report, Base Line Forecasts of Resource Recovery.

2. Midwest Research Institute, Draft Report, Profile Analysis of Nine Beverage Container Alternatives.

TABLE 2

Energy Savings of Source Reduction Program-
Reusable Beer and Soft Drink Containers

(1980)

Container Type	Beverage Delivered (Million Oz.)[1]		Energy Required Per Million Oz. (million Btu's)	Energy Consumed (trillion Btu's)		Energy Saving of All Returnable System (trillion Btu's)
	Projected System	All Returnable System		Projected System	All Returnable System	
Returnable Glass Bottle	295,673	1,406,980	184	54	259	(205)
One Way Glass Bottle	385,253	-	550	212	-	212
Aluminum Can	301,998	-	747	226	-	226
Bi-Metal (Steel) Can	424,056	-	443	188	-	188
Total	1,406,980	1,406,980		680	259	421

1. Midwest Research Institute, Draft Report, Base Line Forecasts of Resource Recovery.

2. Midwest Research Institute, Draft Report, Profile Analysis of Nine Beverage Container Alternatives.

TABLE 3

Energy Savings of Source Reduction Program-
Decreased Packaging Materials (Excluding Beverage Containers)
(1971 & 1980)

Packaging Material	Total Consumption (thousand tons)[1]			Consumption at 1958 per capita levels (thousand tons)[2]		Potential Material Savings (thousand tons)		Energy Requirement Per ton (thousand Btu's)[3]	Potential Energy Savings (trillion Btu's)	
	1958	1971	1980	1971	1980	1971	1980		1971	1980
Paper	16,552	27,700	39,086	21,137	25,043	6,563	14,043	40,800[4]	267.8	573.0
Glass	5,063	4,900	6,608	6,465	7,660	(1,565)	(1,052)	15,256	(23.9)	(16.0)
Steel	5,340	5,235	6,168	6,819	8,079	(1,584)	(1,911)	29,590	(46.8)	(56.5)
Aluminum	97	212	507	124	147	88	360	196,632	17.3	70.8
Plastics	368	2,900	5,607	470	557	2,430	5,050	36,000	87.5	181.8
Total	27,420	40,947	57,976	35,015	41,486	5,932	16,490		322.5	753.1

(1) Second Report to Congress on Resource Recovery and Source Reduction, U.S., EPA 1974.

(2) Assumes a return to an equivalent 1958 packaging materials mix (i.e. the percentage of each material used in packaging is assumed to be constant). Economic growth, and increased standards of living, is allowed for by increasing total packaging required by a growth factor (the rate of increase in non-durable goods purchased).

(3) Gordian Associates, Energy Consumption for Six Basic Materials Industries, EPA Draft Report.

(4) Approximately 40% of this energy value is derived from the Btu's contained in the raw material (wood), not from purchased fuels.

TABLE 4

Energy Savings of Source Reduction Program-
Decreased Packaging Consumption

Year	A. Energy Saved From Beverage Container Reusable System (trillion Btu's)	A. B/DOE[1] (000)	B. Energy Saved From Reduction in All Other Packaging Materials (trillion Btu's)	B. B/DOE[1] (000)	A. + B. Total Energy Saved All Packaging Materials (trillion Btu's)	A. + B. B/DOE[1] (000)
1[illegible]1	244	115	322	152	566	267
1980	421	199	753	356	1174	555

[1]Barrels of oil per day equivalent

TABLE 5

Energy Savings of Source Reduction Program-
Impact of Beverage Container Reuse on Potential
Energy Savings from Materials Recycling

	Materials Used in Beverage Containers 1972 (million tons)[1]	Materials Used if All-refillable System Existed 1972 (million tons)[2]	Material Removed from the Waste Stream (million tons)	Percent Recoverable by Materials Recovery[3]	Material Not Recovered (million tons)	Energy Savings Per Ton Recycled (million Btu's)[4]	Potential Material Recovery Energy Saving "Lost" (trillion Btu's
Aluminum	.545	-	.545	50	.273	200	55
Steel	2.000	-	2.000	65	1.300	12	16
Glass	6.200	2.500	3.700	50	1.850	1.3	2
Total	8.745	2.500	6.245	-	3.423	-	73[5]

(1) Second Report to Congress on Resource Recovery and Source Reduction, U.S., EPA 1974.

(2) EPA Analysis based on Midwest Research Institute, Draft Report, Beverage Container Analysis.

(3) Municipal Recovery Systems would receive 72% of total waste stream, recovery efficiency of system is: glass 70%, steel 90%, aluminum 70%.

(4) EPA Analysis.

(5) This energy "loss" of 73 trillion Btu's is smaller than the energy savings (244 trillion Btu's) from reusing beverage containers.

TABLE 6

Energy Savings of Source Reduction Program-
Impact of Reduced Packaging Consumption on Potential
Recovery of Energy from Solid Waste

	Paper	Plastics	Total
Potential Materials Savings from Reduced Packaging Consumption (million tons)[1]	6.6	2.4	9.0
less: Portion not entering the waste stream (million tons)	2.0[2]	.4[3]	2.4
Net amount of materials not available to the total waste stream	4.6	2.0	6.6
less: 28 percent, the waste generated outside of SMSA's[4]	1.3	.6	1.9
Net amount of materials not available to the SMSA waste stream[4]	3.3	1.4	4.7
Btu's per ton of combustible material (million Btu's)[5]	14.8	24.0	
Btu's not available to energy recovery systems (trillion Btu's)	48.8	33.6	82.4[6]

(1) From Table 3.

(2) It was estimated that 30 percent of the paper does not enter the municipal waste stream because of recycling and diversions into other waste streams (water, industrial waste, scrap, etc.).

(3) It was estimated that 15 percent of the plastics does not enter the municipal waste stream for the reasons stated in Note 2, above.

(4) In the estimates of energy recoverable from solid waste, it was assumed that energy recovery is feasible only in SMSA's (Standard Metropolitan Statistical Areas), where economies of scale can be realized.

(5) Assuming paper at 7,400 Btu's per pound and plastic at 12,000 Btu's per pound.

(6) This energy "loss" of 82. trillion Btu's is smaller than the energy savings (322.5 trillion Btu's) from reduced packaging consumption.

TABLE 7

Energy Savings of Source Reduction Program-
Four "Maximum Possible" Energy Conservation Scenarios (1972)
(trillion Btu's)

	Scenario 1 Source Reduction and Energy Recovery	Scenario 2 Source Reduction and Materials Recovery	Scenario 3 Energy Recovery and Materials Recovery	Scenario 4 Source Reduction, Energy Recovery, and Materials Recovery
Source Reduction				
A Reusable Beverage Containers	244	244	-	244
B. Reduced Consumption of All Other Packaging	322	322	-	322
Energy Recovery	750	-	832	750
Materials Recovery	-	99	172	99
Total	1,316	665	1,004	1,415

APPENDIX II

METHODOLOGY FOR DETERMINING THE AMOUNT OF ENERGY POTENTIALLY RECOVERABLE FROM WASTE

by Robert A. Lowe

Theoretical Energy Potential

The amount of energy that could theoretically have been recovered from all the residential and commercial solid waste generated in the U.S. in 1971 is estimated to be 1.1 quadrillion (1.1×10^{15}) Btu's (British Thermal Units) (Table 2 in the text). This is simply a function of (1) the total U.S. population in 1970 (207.0 million); (2) the average amount of residential and commercial solid waste generated (3.32 pounds per person per day, or 125 million tons per year for the entire country); and (3) the energy content of residential and commercial solid waste (4500 Btu per pound).

By 1980, the amount of energy theoretically recoverable from waste is projected to be 1.4 quadrillion Btu's. The increase over 1971 is the result of the projected growth in population and the projected growth in the amount of waste generated per person. The population growth rate reflects the 1970 Series E projections (an increase of 9.3 percent between 1970 and 1980) of the Bureau of Census, U.S. Department of Commerce. The projected per capita waste generation rate for 1980 (an average of 3.91 pounds per person per day) reflects an annual increase of about 1 percent.

All of the basic assumptions--waste generation rate, energy content of waste, population projections and conversion factor to barrels of oil--and why they were selected will be discussed below.

Available Energy Potential

The estimates of the energy potentially recoverable from the residential and commercial wastes generated in Standard Metropolitan Statistical Areas (SMSA's) were made in the same way as those above, with one exception. It was assumed that the average person in an SMSA generates more waste than his rural counterpart. Accordingly, for 1971 a waste generation rate of 3.60 pounds per person per day (4.33 in 1980) was applied to the SMSA population of 140.9 million persons (152.6 million in 1980).

Projected Implementations of Energy Recovery Systems by 1980

This is a projection of energy recovery systems that could be operating by 1980. Unlike the two preceding categories, however, this projection was not made as a function of population; nor was it made solely on the basis of residential and commercial solid waste. Most of the cities and counties included as Projected Implementations (Table 3 in the text) are communities that have taken some definite steps toward implementing an energy recovery system. For example, a few have already begun construction; several others are soliciting proposals from builders and system developers; and in other communities, the legislative body has voted to implement a

system. Several of the communities on the list have not taken such definite steps, but they were included because they have an active planning effort directed towards the energy recovery option.

A brief description of what is taking place in each community listed in Table 3 is included in Exhibit 1. This information was supplied by state and local government officials, representatives of electric utilities and other private companies, and staff of the U.S. Environmental Protection Agency.

It is likely that there will be more energy recovery systems operating by 1980 than Table 3 indicates. This is because there is enough time between the present and 1980 to begin and complete the three to four year implementation process, including planning, design, construction and shakedown.

Potential Candidates: Areas Where Local Conditions Favor Energy Recovery

The list of Potential Candidates (Table 4 in the text) identifies those areas (SMSA's) where certain local conditions in 1974 favor implementation of an energy recovery system by 1980.

As in the first two categories, the energy recoverable from potential candidate areas is a function of population. Being based on the entire population of each area, the projections assume that all the residential and commercial waste generated in each area would be included in energy recovery systems. It may happen that these communities

may chose to put only part--or even none--of their wastes through an energy recovery system. On the other hand, some communities may recover energy from other wastes (such as tires, waste oil and wood chips) that are not included in the residential and commercial waste categories. Nevertheless, all the residential and commercial wastes (and only those wastes) were used as the basis for the projections in order to provide a reasonable "maximum possible" estimate.

The potential candidates were identified using three local conditions as screening criteria:

1. Markets
2. Economics
3. Public Interest

To be considered a Potential Candidate, an area must have, as a minimum, suitable markets to take advantage of existing technology. As a second but critical consideration, an area must have certain economic conditions, such as high disposal costs and high alternative fuel costs. Thirdly, the public must be interested in energy recovery. In certain cases, public interest is so keen that public officials have been encouraged to implement energy recovery even though economic conditions may not warrant it. These criteria were applied in turn to each of the 243 SMSA's ranked by population by the Bureau of Census. (Exhibit 2).

Markets. SMSA's were first screened to determine if suitable markets for waste-based energy are available within a reasonable distance.

The best market approach was assumed to be the use of solid waste as a supplementary fuel in existing electric utility boilers. Use of waste as a fuel for heating downtown areas (district heating) and for industrial boilers is also possible; but data on the location and capacity of these boilers are too limited to screen SMSA's on the basis of these markets. Therefore, each area was examined only for the location of electric utility power plants that are potentially capable of burning solid waste as a fuel. Any utility boiler that was designed to burn coal was considered to be potentially capable of handling solid waste because of its ash handling capability. And if a coal-burning utility boiler were not located in or near an SMSA, that SMSA was excluded from consideration.

Certain exceptions were made. The San Diego SMSA has no ash-handling boilers nearby but was included because it is implementing an EPA-supported oil pyrolysis demonstration plant; San Diego County is planning to utilize pyrolysis on a larger scale if the demonstration is successful. Miami and Jacksonville, Florida, are faced with a critical shortage of disposal space because of a high water table and population density; this primarily economic condition is expected to force these areas to attempt to find markets for waste-based energy even though no suitable utility boilers are available. San Antonio is included because its municipally-owned utility is seriously considering building a new coal-and-waste-burning power plant. Eugene, Oregon (in Lane County) is included because the County is considering retrofitting

its boilers to supplement decreasing supplies of its primary fuel, wood wastes.

Economics. The second screening was made on the basis of three economic criteria:

1. Population size
2. Alternative disposal costs
3. Alternative fuel costs

Energy recovery systems require large quantities of waste (at least 200 to 250 tons per day) delivered for processing at one site in order to achieve economies of scale. To generate 200 tons per day, a population of about 100,000 persons is typically required[1] (assuming each person generates 3.60 pounds per day and the plant operates five days a week). All but 26 SMSA's have a population over 100,000.

Alternative disposal costs are frequently the most important economic factor. The most common influence on disposal costs is the availability of land nearby. Many communities, especially in the cities and suburbs, have land that is undeveloped but not available for disposal because of local resident opposition, high property values or adverse physical conditions (e.g., high water table). These communities must seek disposal sites farther away and, consequently,

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[1]There will be exceptions to this somewhat arbitrary minimum size requirement. Ames, Iowa, (population 40,000) for example, is about to begin construction on a 200 ton per day energy recovery system.

bear the additional transportation costs.

Most of the SMSA's listed as potential candidates were found to be approaching the limit of present disposal site capacity and having difficulty in obtaining additional capacity. This is a particularly critical problem in the densely populated Northeast. By comparison, cities like San Francisco and Los Angeles appear to have found long term disposal capacity in relatively nearby canyons.

As alternative fuel costs increase, the economics of energy recovery become more favorable because the value of the waste-based energy is usually measured by the value of the fuel that it replaces. High fuel costs, however, have only minor significance in decisions to implement energy recovery because of the small potential impact on the economics of the fuel user, especially the electric utility. Nevertheless, it became apparent that most SMSA's that qualified as Potential Candidates had higher fuel costs than non-candidates. Again, this is especially true in the densely populated Northeast, where the more expensive fuels (low sulfur coal and oil) are required to meet stricter environmental standards.

Public Interest. Public interest in energy recovery has become an increasingly important influence on the public decision-making process, especially as public officials have become more sensitive to environmental and energy issues. In communities where public officials are considering energy recovery as an option based on their perception of its economic,

environmental and political benefits, these public officials appear to have, as a minimum, the tacit support of their constituents. In some communities where conditions do not readily favor energy recovery (for example, sufficient land disposal capacity is available), the public's interest in environmental issues is so strong that public officials are planning to implement (or are now implementing) energy recovery systems anyway. This strong public support for environemental issues is evident in several states, including Colorado, Connecticut and Oregon.

These three screening criteria were applied to each SMSA. In evaluating each SMSA as a possible Potential Candidate, certain factors were more important than others. Exhibit 3 indicates the criteria that determined the judgment about each SMSA.

Waste Generation Rates

The following per capita waste generation rates were used in the calculations of recoverable energy:

	Pounds per person per day	
	1971	1980
U.S. National Average	3.25	3.91
Urbanized Area Average	3.60	4.33

These rates were based upon the estimated 125 million tons of solid waste generated in the U.S. in 1971. The types of waste included in this estimate were described in the text.

Heating Value of Waste

The higher heating value of 4,500 Btu per pound (9 million Btu per ton) is generally accepted as the energy value of "as received," unprocessed waste as delivered by a collection truck to a processing or disposal facility.

Different waste processing methods have different recovery efficiencies. For example, a shredding/air classification waste processing system loses some potential energy by removing heavy combustibles from the fuel fraction, while high temperature incineration with no prior classification would lose far less potential energy. However, no adjustment was made to allow for such processing losses or energy conversion efficiencies (of, say, steam to electricity) because no prejudgment can be made as to which energy recovery method would be used in any given situation.

Population Projections

Series E Projections, indicating a 9.3 percent increase between 1970 and 1980, were used to project the population of the U.S. in 1980. The same projections were applied to all SMSA's, although it is likely that some SMSA's will grow more than others.

Series E Projections are one of the several population projections made by the Bureau of Census, U.S. Department of Commerce based upon projected birth, death, immigration and emigration rates. Series E was selected because it is the best approximation of current rates of birth, death, and so on.

Barrels of Oil Per Day

Energy data are frequently reduced to a common term of measurement to facilitate comparability. British Thermal Units (Btu's) and Barrels per Day of Oil Equivalent (B/DOE) are the most common. B/DOE were calculated based on the following factors:

1 barrel of crude oil = 5.8 million Btu's

1 year = 365 days

EXHIBIT I

Projected Implementations of Energy Recovery Systems by 1980

Location	Tons Per Day	Description
California		
San Diego County	200	Pyrolysis; U.S. EPA is sponsoring project to demonstrate the Garrett Research and Development system; oil produced will be accepted by San Diego Gas and Electric; project in engineering design phase
Connecticut		
Bridgeport	1,200	Solid waste as fuel; State-wide resource recovery authority is reviewing proposals; Northeast Utilities will accept the fuel
District of Columbia	1,000	Solid waste as fuel; D.C., Fairfax County, Arlington County, the City of Alexandria, and the Council of Governments are studying the feasibility of implementing a supplemental fuel system on a region-wide basis; Virginia Electric Power Company and Potomac Electric Power Company are cooperating in the studies
Illinois		
Chicago	2,000	Solid waste as fuel; construction started in early March; Commonwealth Edison will accept the fuel
Chicago area excluding the City	1,000	Solid waste as fuel; several suburbs have approached Commonwealth Edison to determine the feasibility of implementing supplemental fuel systems

Iowa		
Ames	200	Solid waste as fuel; construction to begin by June, 1974; municipal electric utility will accept the fuel
Maryland		
Baltimore	1,000	Pyrolysis; U.S. EPA is sponsoring project to demonstrate the Monsanto system; pyrolysis gas will be combusted on-site to generate steam for sale to Baltimore Gas and Electric; plant will be operational in early 1975
Montgomery County	1,200	Solid waste as fuel; County is planning project with Potomac Electric Power Company cooperation; feasibility study has been completed; County Council and County Executive have approved the plan
Massachusetts		
Braintree	240	Water wall incineration; plant has been operating since 1972; Contract signed early 1974 for sale of steam to Weymouth Art Leather, Co.
East Bridgewater (near Brockton)	1,200	Solid waste as fuel; Combustion Equipment Associates and others; privately financed processing facility; Weyerhauser is accepting the fuel for their industrial steam boilers
Saugus (near Boston)	1,200	Water wall incineration; plant under construction; steam product will be sold to General Electric Co. for process steam
Lawrence	1,000	Solid waste as fuel; Lawrence will be the first implementation under the State-wide solid waste master plan approved in early 1974; master plan calls for supplemental fuel production for steam and steam-electric boilers, and materials recovery

Missouri		
St. Louis	8,000	Solid waste as fuel; Union Electric Company plans to implement, by mid-1977, a system to handle the residential, commercial and selected industrial waste from the entire metropolitan area; U.E. will process raw waste, recover magnetic metal, aluminum, and glass as well as fuel for their boilers
New Jersey		
Essex County (Newark area)	1,000	Solid waste as fuel; Request For Proposals is being prepared; supplemental fuel to be accepted by Public Services Gas and Electric or other industrial steam boilers
Hackensack Meadowlands	2,000	Solid waste as fuel; detailed proposals are currently being reviewed; it is anticipated that the fuel will be accepted by Public Services Gas and Electric or industrial steam boilers
Union County (Elizabeth), or Middlesex County (New Brunswick)	1,000	Solid waste as fuel; feasibility of producing a supplemental fuel for Public Services Gas and Electric is being assessed
New York		
Albany area	500	Solid waste as fuel; feasibility of producing supplemental fuel for industrial steam boilers, state-owned heating plant, and municipal electric utility is being assessed
Hempstead	1,000	Detailed proposals have been received for design and construction of energy and materials recovery systems
Monroe County (Rochester)	500	Solid waste as fuel; feasibility study to produce a supplemental fuel for Rochester Gas and Electric completed; Request For Proposals being prepared

New York City	2,000	Solid waste as fuel; City has completed feasibility study of using City waste as supplemental fuel in Commonwealth Edison's boilers; City writing Request For Proposals to design and construct supplemental fuel facility; City and Commonwealth Edison also plan to initiate contract in Spring 1974 to determine feasibility of designing new steam-electric boiler to burn 50% solid waste
Westchester County (White Plains)	1,500	Feasibility study for solid waste disposal completed; County most interested in energy recovery for County-owned industrial park
Ohio		
Akron	1,000	Water wall incineration; detailed engineering study is underway; steam product will be used for downtown heat and air conditioning and for B.F. Goodrich process steam
Cleveland	500	City has requested and received bids for a steam generation system; the super-heated steam product will be used for electric generation by the municipal utility
Oregon		
Lane County (Eugene)	700	Solid waste as fuel; feasibility study completed to use waste as supplemental fuel in a Eugene municipal steam power plant that currently burns wood waste; additional waste fuel is required because wood wastes are becoming scarce
Pennsylvania		
Philadelphia	2,400	Solid waste as fuel; Combustion Equipment Associates has announced plans to construct and operate, with private financing, a facility to produce supplemental fuel for industrial steam boilers

Puerto Rico		
San Juan	1,000	San Juan planning to initiate feasibility study for a solid waste as fuel system; supplemental fuel would be used by Commonwealth-owned San Juan steam-electric station
Tennessee		
Knoxville	500	Pyrolysis; Tennessee Valley Authority is studying the feasibility of implementing a Torrax gas pyrolysis system to produce gas as supplemental fuel for an adjacent TVA steam-electric boiler
Memphis	500	Solid waste as fuel; detailed proposals have been requested to implement a wet processing system to produce supplemental fuel for a Tennessee Valley Authority steam-electric boiler
Nashville	750	Water wall incineration; construction is complete; public authority has been formed to construct and operate the facility; steam product will be used for downtown heating and air conditioning

Exhibit 2

Rank of Standard Metropolitan Statistical Areas in the United States by Population: 1970

Rank	1970 SMSA's	Population
1	New York, N.Y.	11,571,899
2	Los Angeles-Long Beach, Calif.	7,032,075
3	Chicago, Ill.	6,978,947
4	Philadelphia, Pa.-N.J.	4,817,914
5	Detroit, Mich.	4,199,931
6	San Francisco-Oakland, Calif.	3,109,519
7	Washington, D.C.-Md.-Va.	2,861,123
8	Boston, Mass.	2,753,700
9	Pittsburgh, Pa.	2,401,245
10	St. Louis, Mo.-Ill.	2,363,017
11	Baltimore, Md.	2,070,670
12	Cleveland, Ohio	2,064,194
13	Houston, Tex.	1,985,031
14	Newark, N.J.	1,856,556
15	Minneapolis-St. Paul, Minn.	1,813,647
16	Dallas, Tex.	1,555,950
17	Seattle-Everett, Wash.	1,421,869
18	Anaheim-Santa Ana-Garden Grove, Calif.	1,420,386
19	Milwaukee, Wis.	1,403,688
20	Atlanta, Ga.	1,390,164
21	Cincinnati, Ohio-Ky.-Ind.	1,384,851
22	Paterson-Clifton-Passaic, N.J.	1,358,794
23	San Diego, Calif.	1,357,854
24	Buffalo, N.Y.	1,349,211
25	Miami, Fla.	1,267,792
26	Kansas City, Mo.-Kans.	1,253,916
27	Denver, Colo.	1,227,529
28	San Bernardino-Riverside-Ontario, Calif.	1,143,146
29	Indianapolis, Ind.	1,109,882
30	San Jose, Calif.	1,064,714
31	New Orleans, La.	1,045,809
32	Tampa-St. Petersburg, Fla.	1,012,594
33	Portland, Oreg.-Wash.	1,009,129
34	Phoenix, Ariz.	967,522
35	Columbus, Ohio	916,228
36	Providence-Pawtucket-Warwick, R.I.-Mass.	910,781
37	Rochester, N.Y.	882,667
38	San Antonio, Tex.	864,014
39	Dayton, Ohio	850,266
40	Louisville, Ky.-Ind.	826,553
41	Sacramento, Calif.	800,592
42	Memphis, Tenn.-Ark.	770,120
43	Fort Worth, Tex.	762,086
44	Birmingham, Ala.	739,274
45	Albany-Schenectady-Troy, N.Y.	721,910
46	Toledo, Ohio-Mich.	692,571
47	Norfolk-Portsmouth, Va.	680,600
48	Akron, Ohio	679,239
49	Hartford, Conn.	663,891
50	Oklahoma City, Okla.	640,889
51	Syracuse, N.Y.	636,507
52	Gary-Hammond-East Chicago, Ind.	633,367
53	Honolulu, Hawaii	629,176
54	Fort Lauderdale-Hollywood, Fla.	620,100
55	Jersey City, N.J.	609,266
56	Greensboro—Winston-Salem—High Point, N.C.	603,895
57	Salt Lake City, Utah	557,635
58	Allentown-Bethlehem-Easton, Pa.-N.J.	543,551
59	Nashville-Davidson, Tenn.	541,108
60	Omaha, Nebr.-Iowa	540,142
61	Grand Rapids, Mich.	539,225
62	Youngstown-Warren, Ohio	536,003
63	Springfield-Chicopee-Holyoke, Mass.-Conn.	529,922
64	Jacksonville, Fla.	528,865
65	Richmond, Va.	518,319
66	Wilmington, Del.-N.J.-Md.	499,493
67	Flint, Mich.	496,661
68	Tulsa, Okla.	476,035
69	Orlando, Fla.	428,003
70	Fresno, Calif.	413,053
71	Tacoma, Wash.	411,027
72	Harrisburg, Pa.	410,626
73	Charlotte, N.C.	408,370
74	Knoxville, Tenn.	400,337
75	Wichita, Kans.	389,352
76	Bridgeport, Conn.	389,153
77	Lansing, Mich.	378,423
78	Mobile, Ala.	376,690
79	Oxnard-Ventura, Calif.	376,430
80	Canton, Ohio	372,210
81	Davenport-Rock Island-Moline, Iowa-Ill.	362,638
82	El Paso, Tex.	359,291
83	New Haven, Conn.	355,538
84	Tucson, Ariz.	351,667
85	West Palm Beach, Fla.	348,753
86	Worcester, Mass.	344,320
87	Wilkes-Barre—Hazleton, Pa.	342,301
88	Peoria, Ill.	341,979
89	Utica-Rome, N.Y.	340,670
90	York, Pa.	329,540
91	Bakersfield, Calif.	329,162
92	Little Rock-North Little Rock, Ark.	323,296
93	Columbia, S.C.	322,880
94	Lancaster, Pa.	319,683
95	Beaumont-Port Arthur, Tex.	315,943
96	Albuquerque, N. Mex.	315,774
97	Chattanooga, Tenn.-Ga.	304,927
98	Trenton, N.J.	303,968
99	Charleston, S.C.	303,849
100	Binghamton, N.Y.-Pa.	302,672
101	Greenville, S.C.	299,502
102	Reading, Pa.	296,382
103	Austin, Tex.	295,516
104	Shreveport, La.	294,703
105	Newport News-Hampton, Va.	292,159
106	Madison, Wis.	290,272
107	Stockton, Calif.	290,208
108	Spokane, Wash.	287,487
109	Des Moines, Iowa	286,101
110	Baton Rouge, La.	285,167
111	Corpus Christi, Tex.	284,832
112	Fort Wayne, Ind.	280,455
113	South Bend, Ind.	280,031
114	Appleton-Oshkosh, Wis.	276,891
115	Las Vegas, Nev.	273,288
116	Rockford, Ill.	272,063
117	Duluth-Superior, Minn.-Wis.	265,350
118	Santa Barbara, Calif.	264,324
119	Erie, Pa.	263,654
120	Johnstown, Pa.	262,822
121	Jackson, Miss.	258,906
122	Lorain-Elyria, Ohio	256,843
123	Huntington-Ashland, W. Va.-Ky.-Ohio	253,743
124	Augusta, Ga.-S.C.	253,460
125	Salinas-Monterey, Calif.	250,071
126	Vallejo-Napa, Calif.	249,081
127	Pensacola, Fla.	243,075
128	Columbus, Ga.-Ala.	238,584
129	Colorado Springs, Colo.	235,972
130	Scranton, Pa.	234,107
131	Ann Arbor, Mich.	234,103
132	Evansville, Ind.-Ky.	232,775
133	Lawrence-Haverhill, Mass.-N.H.	232,415
134	Charleston, W. Va.	229,315
135	Raleigh, N.C.	228,453
136	Huntsville, Ala.	228,239
137	Hamilton-Middletown, Ohio	226,207
138	Saginaw, Mich.	219,743

Rank	1970 SMSA's	Population
139	Eugene, Oreg.	213,358
140	Lowell, Mass.	212,860
141	Fayetteville, N.C.	212,042
142	Waterbury, Conn.	208,956
143	New London-Groton-Norwich, Conn.	208,412
144	Stamford, Conn.	206,419
145	Macon, Ga.	206,342
146	Santa Rosa, Calif.	204,885
147	Kalamazoo, Mich.	201,550
148	Montgomery, Ala.	201,325
149	Modesto, Calif.	194,506
150	Durham, N.C.	190,388
151	Brockton, Mass.	189,820
152	Savannah, Ga.	187,767
153	Salem, Oreg.	186,658
154	Wheeling, W. Va.-Ohio	182,712
155	McAllen-Pharr-Edinburg, Tex.	181,535
156	Roanoke, Va.	181,436
157	Lubbock, Tex.	179,295
158	Terre Haute, Ind.	175,143
159	Atlantic City, N.J.	176,043
160	Lexington, Ky.	174,323
161	Lima, Ohio	171,472
162	Racine, Wis.	170,838
163	Galveston-Texas City, Tex.	169,812
164	Lincoln, Nebr.	167,972
165	Steubenville-Weirton, Ohio-W. Va.	165,627
166	Champaign-Urbana, Ill.	163,281
167	Cedar Rapids, Iowa	163,213
168	Springfield, Ill.	161,335
169	Fort Smith, Ark.-Okla.	160,421
170	Green Bay, Wis.	158,244
171	Muskegon-Muskegon Heights, Mich.	157,426
172	Springfield, Ohio	157,115
173	Topeka, Kans.	155,222
174	Springfield, Mo.	152,929
175	New Bedford, Mass.	152,642
176	Fall River, Mass.-R.I.	149,976
177	Waco, Tex.	147,553
178	Lake Charles, La.	145,415
179	New Britain, Conn.	145,269
180	Asheville, N.C.	145,056
181	Amarillo, Tex.	144,396
182	Jackson, Mich.	143,274
183	Portland, Maine	141,625
184	Brownsville-Harlingen-San Benito, Tex.	140,368
185	Anderson, Ind.	138,451
186	Provo-Orem, Utah	137,776
187	Altoona, Pa.	135,356
188	Biloxi-Gulfport, Miss.	134,582
189	Waterloo, Iowa	132,916
190	Mansfield, Ohio	129,997

Rank	1970 SMSA's	Population
191	Muncie, Ind.	129,219
192	Petersburg-Colonial Heights, Va.	128,809
193	Wichita Falls, Tex.	127,621
194	Ogden, Utah	126,278
195	Decatur, Ill.	125,010
196	Lynchburg, Va.	123,474
197	Vineland-Millville-Bridgeton, N.J.	121,374
198	Reno, Nev.	121,068
199	Fargo-Moorhead, N. Dak.-Minn.	120,238
200	Norwalk, Conn.	120,099
201	Pueblo, Colo.	118,238
202	Kenosha, Wis.	117,917
203	Bay City, Mich.	117,339
204	Sioux City, Iowa-Nebr.	116,189
205	Tuscaloosa, Ala.	116,029
206	Monroe, La.	115,387
207	Abilene, Tex.	113,959
208	Boise City, Idaho	112,230
209	Lafayette, La.	109,716
210	Lafayette-West Lafayette, Ind.	109,378
211	Manchester, N.H.	108,461
212	Lawton, Okla.	108,144
213	Wilmington, N.C.	107,219
214	Gainesville, Fla.	104,764
215	Bloomington-Normal, Ill.	104,389
216	Tallahassee, Fla.	103,047
217	Texarkana, Tex.-Ark.	101,198
218	Fitchburg-Leominster, Mass.	97,164
219	Tyler, Tex.	97,096
220	Sioux Falls, S. Dak.	96,209
221	Gadsden, Ala.	94,144
222	Odessa, Tex.	91,805
223	Dubuque, Iowa	90,609
224	Albany, Ga.	89,639
225	Billings, Mont.	87,367
226	St. Joseph, Mo.	86,915
227	Pine Bluff, Ark.	85,329
228	Rochester, Minn.	84,104
229	Sherman-Denison, Tex.	83,225
230	Great Falls, Mont.	81,804
231	Columbia, Mo.	80,911
232	La Crosse, Wis.	80,468
233	Pittsfield, Mass.	79,727
234	Owensboro, Ky.	79,486
235	Danbury, Conn.	78,405
236	Laredo, Tex.	72,859
237	Lewiston-Auburn, Maine	72,474
238	San Angelo, Tex.	71,047
239	Nashua, N.H.	66,456
240	Bristol, Conn.	65,808
241	Midland, Tex.	65,433
242	Bryan-College Station, Tex.	57,978
243	Meriden, Conn.	55,959

Exhibit 3

Screening of Standard Metropolitan Statistical Areas (SMSA's)

to Select Potential Candidates in 1974

(CAPITAL LETTERS DESIGNATE POTENTIAL CANDIDATES)

Rank	SMSA	Screening Criteria: Markets	Economics	Public Interest	Comments
1	NEW YORK, N.Y.	Y	F*	A	Critical disposal problem. See Projected Implementations.
2	Los Angeles-Long Beach, Calif.	N	U	A	Ample disposal capacity in canyons. Some development work in methane recovery from landfill.
3	CHICAGO ILL.	Y	F	S	See Projected Implementations.
4	PHILADELPHIA, PA.-N.J.	Y	F	N	See Projected Implementations.
5	DETROIT, MICH.	Y	F	A	New city administration appears receptive to resource recovery. Some private companies recovering their own waste as fuel for their own boilers.
6	San Francisco-Oakland, Calif.	N	U	A	Long-term landfill commitments.
7	WASHINGTON, D.C.-MD.-VA.	Y	F	A	See Projected Implementations. (Washington, D.C. and Montgomery County, Md.).
8	BOSTON, MASS.	Y	F	S	See Projected Implementations. (Saugus, Braintree). Statewide resource recovery plan approved by Governor.
9	PITTSBURGH, PA.	Y	F	N	
10	ST. LOUIS, MO.-ILL.	Y*	F	S	Site of EPA/City/Union Electric demonstration Currently planning to expand. See Projected Implementations.

LEGEND for Exhibit 3

Markets

- Y — Yes, electric utility boilers with ash handling capability are available.
- N — No, electric utility boilers with ash handling capability are not available.
- E — Exception. Ash-handling electric utility boilers are not available but this SMSA has made other arrangements. See text.

Economics

- F — Favorable economic condition for resource recovery. Generally this is an indication that conventional incineration is too expensive and that land for disposal is probably not available because of population density, high water table, or political opposition to a new disposal site.
- M — Marginal economic conditions. The economic conditions may be conducive to resource recovery.
- U — Unfavorable economic conditon for resource recovery. Generally this means that land is available for disposal.

Public Interest

- S — Strong. Public interest in resource recovery is desired even if economic conditions are unfavorable or marginal.
- A — Adequate public interest.
- N — Nominal public interest.
- O — Strong interests oppose resource recovery.

*This factor was significantly more important than other factors in the decision to designate this SMSA as a Potential Candidate.

Rank	SMSA	Screening Criteria: Markets	Economics	Public Interest	Comments
11	BALTIMORE, MD.	Y	F	S	Site of EPA/City/State gas pyrolysis demonstration. See Projected Implementations.
12	CLEVELAND, OHIO	Y	F	A	See Projected Implementations.
13	Houston, Tex.	N	U	N	
14	NEWARK, N.J.	Y	F	A	See Projected Implementations.
15	MINN.-ST. PAUL, MINN.	Y	F	A	State has appropriated $1.5 million in seed money for statewide resource recovery implementation.
16	Dallas, Tex.	N	U	N	
17	Seattle-Everett, Wash.	N	M	A	
18	Anaheim-Santa Ana-Garden Grove, Calif.	N	U	A	
19	MILWAUKEE, WIS.	Y	F	S	State has approved statewide recycling plan.
20	ATLANTA, GA.	Y	F	N	City and DeKalb County are considering use of solid waste as fuel in conjunction with EPA grant for rail haul demonstration.
21	CINCINNATI,O.-KY.-IND.	Y	F	N	
22	PATERSON-CLIFTON-PASSAIC, N.J.	Y	F	A	
23	SAN DIEGO, CALIF.	E	M	S	Site of EPA/County oil pyrolysis demonstration. See Projected Implementations.
24	BUFFALO, N.Y.	Y	F	S	Erie County is considering recycling plan.
25	MIAMI, FLA.	E	F*	A	

LEGEND for Exhibit 3

Markets

- Y — Yes, electric utility boilers with ash handling capability are available.
- N — No, electric utility boilers with ash handling capability are not available.
- E — Exception. Ash-handling electric utility boilers are not available but this SMSA has made other arrangements. See text.

Economics

- F — Favorable economic condition for resource recovery. Generally this is an indication that conventional incineration is too expensive and that land for disposal is probably not available because of population density, high water table, or political opposition to a new disposal site.
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*This factor was significantly more important than other factors in the decision to designate this SMSA as a Potential Candidate.

Rank	SMSA	Screening Criteria			Comments
		Markets	Economics	Public Interest	
26	Kansas City, Mo.-Kans.	N	U	N	
27	DENVER, COLO.	Y	M	S*	
28	San Bernadino-Riverside-Ontario, Calif.	N	U	A	
29	Indianapolis, Ind.	Y	U	N	
30	San Jose, Calif.	N	U	A	
31	New Orleans, La.	N	U	N	New Orleans is planning a materials recovery system, but combustible fraction will be landfilled.
32	Tampa-St. Petersburg, Fla.	N	M	N	
33	PORTLAND, ORE.-WASH.	N	M	S*	
34	Phoenix, Ariz.	N	U	N	
35	COLUMBUS, OHIO	Y	M	A	
36	PROVIDENCE-PAWTUCKET WARWICK, R.I.-MASS.	Y	F	S	Governor and State Legislature are studying the feasibility of a statewide recycling system.
37	ROCHESTER, N.Y.	Y	F	A	See Projected Implementations.
38	SAN ANTONIO, TEX.	Y	F	A	Municipally-owned utility is planning to build a coal-fired boiler to handle solid waste.
39	Dayton, Ohio	Y	M	A	
40	LOUISVILLE, KY.-IND.	Y	M	S	
41	Sacramento, Calif.	N	M	A	

LEGEND for Exhibit 3

Markets

- Y — Yes, electric utility boilers with ash handling capability are available.
- N — No, electric utility boilers with ash handling capability are not available.
- E — Exception. Ash-handling electric utility boilers are not available but this SMSA has made other arrangements. See text.

Economics

- F — Favorable economic condition for resource recovery. Generally this is an indication that conventional incineration is too expensive and that land for disposal is probably not available because of population density, high water table, or political opposition to a new disposal site.
- M — Marginal economic conditions. The economic conditions may be conducive to resource recovery.
- U — Unfavorable economic conditon for resource recovery. Generally this means that land is available for disposal.

Public Interest

- S — Strong. Public interest in resource recovery is desired even if economic conditions are unfavorable or marginal.
- A — Adequate public interest.
- N — Nominal public interest.
- O — Strong interests oppose resource recovery.

*This factor was significantly more important than other factors in the decision to designate this SMSA as a Potential Candidate.

Rank	SMSA	Screening Criteria			Comments
		Markets	Economics	Public Interest	
42	MEMPHIS, TENN.-ARK.	Y	F	S	See Projected Implementations.
43	Fort Worth, Tex.	N	U	N	
44	Birmingham, Ala.	Y	U	N	
45	ALBANY-SCHENECTADY-TROY, N.Y.	Y	F	S	See Projected Implementations.
46	TOLEDO, OHIO-MICH.	Y	F	A	
47	Norfolk-Portsmouth, Va.	Y	U	A	
48	AKRON, OHIO	Y	F	A	
49	HARTFORD, CONN.	Y	F	S	Statewide recycling program in effect.
50	Oklahoma City, Okla.	N	U	N	
51	Syracuse, N.Y.	Y	U	N	
52	GARY-HAMMOND-EAST CHICAGO, IND.	Y	F	N	
53	Honolulu, Hawaii	N	F	A	
54	Fort Lauderdale-Hollywood, Fla.	N	F	N	
55	JERSEY CITY, N.J.	Y	F	A	
56	Greensboro--Winston-Salem--High Point, N.C.	Y	U	A	
57	Salt Lake City, Utah	N	U	N	

LEGEND for Exhibit 3

Markets

- Y — Yes, electric utility boilers with ash handling capability are available.
- N — No, electric utility boilers with ash handling capability are not available.
- E — Exception. Ash-handling electric utility boilers are not available but this SMSA has made other arrangements. See text.

Economics

- F — Favorable economic condition for resource recovery. Generally this is an indication that conventional incineration is too expensive and that land for disposal is probably not available because of population density, high water table, or political opposition to a new disposal site.
- M — Marginal economic conditions. The economic conditions may be conducive to resource recovery.
- U — Unfavorable economic conditon for resource recovery. Generally this means that land is available for disposal.

Public Interest

- S — Strong. Public interest in resource recovery is desired even if economic conditions are unfavorable or marginal.
- A — Adequate public interest.
- N — Nominal public interest
- O — Strong interests oppose resource recovery.

*This factor was significantly more important than other factors in the decision to designate this SMSA as a Potential Candidate.

Rank	SMSA	Screening Criteria: Markets	Economics	Public Interest	Comments
58	Allentown-Bethlehem-Easton, Pa.-N.J.	Y	U	M	
59	NASHVILLE-DAVIDSON, TENN.	E	F	S	See Projected Implementations.
60	Omaha;Nebr.-Iowa	Y	M	M	
61	Grand Rapids, Mich.	Y	U	A	
62	Youngstown-Warren, Ohio	Y	U	M	
63	Springfield-Chicopee-Holyoke, Mass.-Conn.	Y	U	S	
64	JACKSONVILLE, FLA.	E	F	S	Municipally-owned utility is seeking solution to common problems of waste disposal and power generation.
65	Richmond, Va.	Y	U	M	
66	WILMINGTON, DEL.-N.J.-MD.	Y	F	S	Site of EPA/State of Delaware resource recovery demonstration.
67	Flint, Mich.	Y	U	M	
68	Tulsa, Okla.	N	U	M	
69	Orlando, Fla.	N	M	M	
70	Fresno, Calif.	N	U	A	
71	Tacoma, Wash.	N	U	M	
72	Harrisburg, Pa.	Y	U	M	
73	Charlotte, N.C.	Y	U	M	
74	KNOXVILLE, TENN.	Y	M	S	See Projected Implementations.

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Markets

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Rank	SMSA	Screening Criteria			Comments
		Markets	Economics	Public Interest	
75	Wichita, Kans.	N	U	N	
76	BRIDGEPORT, CONN.	Y	F	S*	Site of first implementation of statewide recycling program. See Projected Implementations.
77	Lansing, Mich.	Y	U	N	
78	Mobile, Ala.	Y	U	N	
79	Oxnard-Ventura, Calif.	N	U	A	
80	Canton, Ohio	Y	U	N	
81	Davenport-Rock Island-Moline, Iowa-Ill.	Y	U	N	
82	El Paso, Tex.	N	U	N	
83	NEW HAVEN, CONN.	Y	F	S*	Statewide recycling plant in effect.
84	Tuscon, Ariz.	N	U	N	
85	West Palm Beach, Fla.	N	M	N	
86	Worcester, Mass.	Y	U	A	
87	Wilkes Barre - Hazelton, Pa.	Y	U	N	
88	PEORIA, ILL.	Y	U	S*	
89	Utica-Rome, N.Y.	Y	U	N	
90	York, Pa.	Y	M	N	
91	Bakersfield, Calif.	N	U	N	

LEGEND for Exhibit 3

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Rank	SMSA	Screening Criteria: Markets	Economics	Public Interest	Comments
92	LITTLE ROCK-NORTH LITTLE ROCK, ARK.	Y	F	S	
93	Columbia, S.C.	Y	U	N	
94	Lancaster, Pa.	Y	M	N	
95	Beaumont-Port Arthur, Tex.	N	U	N	
96	Albuquerque, N. Mex.	N	U	N	
97	CHATTANOOGA, TENN.-GA.	Y	M	S*	
98	Trenton, N.J.	Y	M	N	
99	Charleston, S.C.	Y	U	N	
100	Binghamton, N.Y.-PA.	Y	U	N	

With the exception of the SMSA's listed below, none of the SMSA's ranked lower than 100 was characterized by economic or public interest conditions in 1974 that would favor resource recovery by 1980. Some of the SMSA's not listed were close to potential waste fuel markets, but this by itself was not enough to consider an SMSA as a Potential Candidate. The following SMSA's are also Potential Candidates:

106	MADISON, WIS.	Y	M	S*	Shredding operation underway. Statewide recycling program recently approved.
116	ROCKFORD, ILL.	Y	M	S*	
133	LAWRENCE-HAVERHILL, MASS.	Y	F	S*	Site of first recycling facility under newly approved statewide recycling program.
134	CHARLESTON, W.VA.	Y*	M	A	Union Carbide is building a 200 ton per day pyrolysis demonstration plant.
139	EUGENE, OREG.	Y	F	S*	See Projected Implementations.
151	BROCKTON, MASS.	Y*	M	A	See Projected Implementations.

LEGEND for Exhibit 3

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APPENDIX III

NATIONAL ENERGY SAVINGS FROM MATERIAL RECYCLING: SOME "MAXIMUM POSSIBLE" ESTIMATES FOR FERROUS METAL, ALUMINUM AND GLASS

by Frank A. Smith

INTRODUCTION

This appendix presents estimates on the potential energy savings from recycling the aluminum, ferrous, and glass fractions of post-consumer residential and commercial solid waste over the time frame 1972-1990. The basic issue is how much energy could be saved on a nationwide basis from the recycling of these three waste materials as substitutes for their virgin material counterparts (i.e., ferrous waste for virgin pig iron, etc.), under what might be referred to as the "maximum possible recovery scenario." This is an attempt to set some practical recycling level within the theoretical quantity limit of total waste generation, but without pretending to consider political or economic obstacles as limits to recovery. Results are summarized for aluminum, ferrous, and glass in Table 1.

ASSUMPTIONS

Without going into great detail, the following basic estimates and assumptions underly the derivation of these results.

1. Total "available" post-consumer waste quantities were projected on the basis of recent EPA estimates of the ferrous, aluminum and glass fractions of residential and commercial solid waste streams, and unpublished contract work by Midwest Research Institute on baseline forecasts. Construction, demolition, industrial, and other possible waste flow sources of material recovery were not considered.

2. Percentage of Waste Material processed for recovery was taken as 100% of the waste generated in Standard Metropolitan Statistical Areas. This amounts to roughly 70 to 74% of total U.S. generation between 1972 and 1974.

3. Recovery process efficiencies were assumed as follows, based on research by Midwest Research Institute:

   Aluminum 65 - 75%
   Ferrous 90%
   Glass 70%

4. Energy savings per ton of material recycled were taken as follows, based on an assessment of available literature and current ongoing contract work, (in 10^6 Btu/ton of material recovery):

   Aluminum 200
   Ferrous 12
   Glass 1.3

CONCLUSIONS

The "maximum possible" energy savings values presented in Table 1 are smaller than many would have guessed, and are in some cases significantly less than other published estimates (e.g. see the report of the National Commission on Materials Policy as well as EPA's First Annual Report to Congress on Resource Recovery). Others have based their estimates on 100% recovery from a larger estimated waste stream, and/or have used higher unit energy savings multipliers for certain materials. There is still much to be learned about this latter question, but the values used here are believed to be the best and most recent presently available engineering estimates.

On the other hand, many will consider our assumption of 100 percent processing of all metropolitan area waste as a very extreme case. And they would, of course, be correct. The objective was to get a first-order approximation to the maximum possible recovery as an upper bound for purposes of discussion and policy input. Later work will be directed not only at "firming-up" these values, but also at providing further evaluation of more realistic expectations.

Whether one thinks the 1972 figure of 172 trillion Btu's is a small or a large number depends on perspective. It is about 0.25% (one-quarter of one percent) of the nation's primary energy (fossil fuel plus hydroelectric plus nuclear) consumption for 1972 (approximately 70,000 trillion Btu). At 5.8 million Btu's per barrel of crude oil, 172 trillion Btu's is equivalent to about 30 million barrels of crude oil. This potential crude oil equivalent would rise to almost 50 million barrels by 1980 and 70 million barrels by 1990.

TABLE 1

NATIONAL ENERGY SAVINGS FROM MAXIMUM POSSIBLE RECYCLING OF ALUMINUM, FERROUS, AND GLASS FRACTIONS OF POST-CONSUMER SOLID WASTE [TRILLIONS OF BTU'S]*

Materials**	1972	1975	1980	1985	1990
Aluminum [46-56%]	82	115	164	212	274
Ferrous [63-67%]	81	87	95	107	116
Glass [50-52%]	8	13	15	16	16
Total Energy	172	215	274	335	406

*Energy savings are based on "total system" analyses which include primary energy required for raw material acquisition and electricity input as well as for principal refining processes.

**Figures in brackets indicate percentages of the individual material in nation-wide solid waste assumed to be recoverable from a "maximum possible" recovery effort. Lower percentages are for earlier years, higher percentages for later years when larger proportions of popula- is expected to reside in SMSA's and when extraction efficiency expected to rise. "Recovery quantities based on residential and commercial solid waste only.

MARKETS AND TECHNOLOGY FOR RECOVERY OF ENERGY FROM SOLID WASTE

BY

STEVEN J. LEVY

U. S. ENVIRONMENTAL PROTECTION AGENCY

MAY 31, 1974

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INTRODUCTION

Energy consumption in the United States grew by 4.8 percent in 1973.[1] Prior to the present energy crisis, experts predicted that energy demand would double between 1970 and 1990.[2] Efforts to achieve independence from foreign energy supplies and increasing consumption have created a demand for new fuel sources.

Municipal solid waste is one raw material currently being discarded that can be "mined" for its energy content. In the U. S. in 1971, 125 million tons of solid waste from residential and commercial sources was discarded with no attempt to recover energy.[3] At 9 million BTU's per ton, this represents some 1,100 trillion BTU's per year, the energy equivalent of 500,000 barrels of oil per day. Of course, not all of this solid waste would be available for recovery, but some 75 percent of it is concentrated in major metropolitan areas where processing plants large enough to be economically feasible could be located.[4] Industrial wastes, and agricultural and forestry wastes represent the equivalent of an additional 2.0 million barrels of oil per day[5], although collection and transportation problems may restrict their use.

Many different approaches to recovering the energy value of refuse are presently being examined. Waterwall incinerators are currently generating steam in a number of U. S. cities. A new waterwall incinerator will be completed in Nashville Tennessee in mid 1974. In Baltimore, Maryland, a pyrolysis system developed by Monsanto that will generate steam is

nearing completion. St. Louis, Mo., is currently demonstrating a system that uses the shredded, combustible portion of solid waste was a coal substitute in a utility boiler. Many communities are considering similar systems and extensions of the concept to oil-fired boilers, and to the use of wetpulped and/or pelletized solid waste as a fuel. Pyrolysis systems are being developed to convert solid waste into liquid and gaseous fuels. Two of the most promising of these systems are the Garrett Research and Development Company's system for producing oil, which is being demonstrated in San Diego County, California, and Union Carbide's system for producing a gaseous fuel, which is being tested by that company at its plant in South Charleston, W. Va. The recovery of methane from landfilled solid waste is being practiced in a pilot plant in Los Angeles, California. Electrical power generation is being explored in an EPA research project being conducted by the Combustion Power Company.

These technologies enable solid waste to be converted into a number of different energy forms, including gaseous, liquid, and solid fuels and steam and electricity. The energy recovery system that should be employed in any particular community depends upon the market for the output product.

The value of a solid waste energy product should be equivalent, on a heat basis, to the value of the fuel which it replaces, less any additional costs incurred in its use. The current fuel crisis has significantly increased the value of the product and reduced the need to provide special incentives to enhance its marketability.

To be marketable, though, the solid waste energy products must have qualities acceptable to the user. Steam and electricity produced from solid waste are equivalent to those products from other sources, but

fuels produced from solid waste are physically and chemically different from their fossil fuel counterparts. Characteristics such as ash content, heat value, corrosiveness, viscosity, and moisture content have to be acceptable to the user. For all energy products derived from solid waste, factors such as reliability, quantity, and availability are also important.

The objectives of this paper are to review the characteristics of energy products available from existing energy recovery systems (or systems under development), to assess the marketability of such energy products, and to identify potential market opportunities.

In the following sections of this paper each major energy product recoverable from solid waste is discussed. These include the solid, liquid, and gasseous fuels, and steam and electricity. The factors affecting the marketability of each product are examined, as well as the market opportunities. The status of the technology to recover the various energy products is also examined. In the final section of this report the various systems and energy products are compared and contrasted.

SOLID, LIQUID AND GASEOUS FUELS

Background

Solid, liquid and gaseous fuels can be produced from solid waste, using a number of systems currently under development. These fuels can be used as a supplement to their fossil fuel counterparts: coal, petroleum and natural gas.

Mixed municipal solid waste has a heating value of approximately 4,500 BTU per pound. The heating value of solid waste is compared to the fossil fuels in Table 1. Further discussion of the characteristics and uses of the fossil fuels is presented in Appendix A.

TABLE 1

APPROXIMATE HEATING VALUE OF FUELS

Fuels	Heat Value
Coal	11,000 to 14,000 BTU per pound
No. 6 Heating Oil	150,000 BTU per gallon
Natural Gas	1,000 to 1,100 BTU per cubic foot
Municipal Solid Waste	4,500 BTU per pound

Marketability of Fuels Derived from Solid Waste

Fuels derived from municipal solid waste will have different physical and chemical properties than conventional fuels and will, therefore, have different handling and combustion characteristics. In order to analyze the potential markets for these fuels it is necessary to identify these

characteristics and evaluate the constraints they will place on using the fuel products.

There are a number of general characteristics that determine the marketability of fuels derived from solid waste regardless of whether they are solid, liquid or gaseous. These include:

a. Quantity of fuel produced - enough of the product must be available to justify any expenses that the user will incur in modifying his facility to accept this new fuel source.

b. Heating value - The heat value of each fuel must be high enough to minimize the effect of the fuel on the boiler or furnace efficiency. Also the costs of transporting, storing and handling the fuel will go up as the heat value goes down because a greater quantity of fuel will have to handled to obtain the same amount of energy.

c. Reliability - A high degree of reliability on the supply of the fuel will increase its value because the user will not have to maintain standby equipment or fuel.

d. Quality - The better the product, the more it will be worth because the customer's cost to use the product will be reduced.

Solid fuels derived from solid waste are currently being used as a supplement to coal in suspension fired utility boilers. They are also being considered for use in conjunction with oil fired units and as a fuel supplement in cement kilns. Some factors that influence the marketability of solid fuels derived from solid waste are:

a. Particle size - Particles must be small enough to permit complete combustion when burned in suspension. This will vary with the type of unit used to burn the fuel, and is particularly important

if there are no burnout grates at the base of the combustion chamber.

b. Ash content - Ash content should be kept to a minimum in order to prevent problems of errosion of the furnace walls and the fuel firing system. Also high ash content can overload the ash removal system and may restrict the value of the bottom ash.

c. Moisture content - Moisture content will effect the heat value of the fuel. If high enough it will reduce the combustion ef ficiency of the unit.

A liquid fuel that can be produced from solid waste using the Garrett Company pyrolysis system is a heavy, oil-like fuel which would be used as a supplement to No. 6 fuel oil in large industrial or utility boilers. Some factors which will influence its marketability include:

a. Viscosity - If viscosity is too high the costs of storing and pumping can be excessive. High viscosity can also cause plug ging of fuel lines.

b. Volumetric heating value - The volumetric heat value (BTU per gallon) will influence the cost of transporting and storing the fuel.

c. Chemical stability - If the fuel undergoes chemical change it will resstrict the length of time it can be stored.

d. Special handling problems - The need to maintain separate storage and firing systems for the solid waste fuel, and to purge the firing systems after the fuel has been burned, places an extra burden on the user which may dimish its value.

Most gaseous fuels produced from solid waste have a lower heating value than natural gas because they contain significant quantities of carbon dioxide and, in some systems, nitrogen. The distance which they can be

transported is limited by the cost of compressing and pumping the gas. As the BTU content goes down this becomes prohibitive.

Potential Market Opportunities For Fuels Derived From Solid Waste

Most markets for solid waste fuels would be large utility or industrial users who could blend 20 to 30 percent solid waste fuel with conventional fuels and still use sufficient quantities of solid waste fuels to justify the costs of special storage and firing facilities. Steam electric power plants because of their large fuel needs and proximity to urban areas, represent an attractive market opportunity for solid waste fuels. Major industrial operations (such as cement plants, steel mills, and paper mills) and district heating/cooling plants also represent potential market outlets.

Steam electric power plants - Electric utilities operating fossil-fuel fired steam electric plants are the most promising market for solid waste produced fuels. They use very large quantities of fuel, and electricity demand is influenced by the same factors that influence solid waste generation - population and industrial and commercial activity. Furthermore, the utility's generating plants are often located in close proximity to the urban area where the solid waste is generated. Their quasi-public structure makes the electric utility industry more conscious of community problems, and more receptive to accepting the costs and risks associated with using these fuels.

Economic gain is the overriding factor influencing a decision of this magnitude. Although savings from using solid waste fuels can only amount to a small fraction of the utility's total fuel costs, other indirect economic incentives can be realized through

improved community relationships. For instance, a utility may more easily gain approval of a new power plant site if it is part of a solid waste disposal/energy recovery program.

Savings in the cost of a solid waste fuel would be effectively passed on to the utility's customers through automatic reductions in the fuel adjustment rider.

Industrial Operations - Many industrial operations are ideal markets for fuel produced from solid waste. Fuel from several hundred tons of solid waste a day or more could be readily utilized in all but the smallest cement plants, paper mills and steel mills, or in many larger manufacturing plants.

A typical paper board mill, for instance uses about 25,000 pounds of steam to produce one ton of boxboard.[6] A small, 360 ton per day plant would require 400,000 pounds of steam per hour, the equivalent yield of 1,200 tons of solid waste per day.

Most paper mills currently burn their own bark and wood waste in these boilers as a supplement to conventional fuels. Although this might reduce the capacity of the market of solid waste fuels somewhat, it should ease the marketing task because the industry is already accustomed to burning waste fuels.

Feasibility studies are currently being done to examine the concept of using solid waste as a fuel in cement manufacturing kilns.[7] The solid waste would be used to supplement the coal or other fuel being used and any ash remaining would be incorporated into the final product. Cement kilns, require about 8 million BTU's of fuel per ton of cement. Plant capacity ranges in size from 1,000 to 3,000 or more per day. Therefore, even a small plant, using refuse as 20 percent

of the fuel load, could handle the fuel produced from 400 tons of solid waste per day.

Systems for Producing Fuels From Solid Waste

The technology for converting solid waste into fuel is very new and is rapidly developing. All of the systems being considered today were conceived since 1968. Nevertheless, several full scale demonstrations are presently (or soon will be) in operation. Additionally, many communities are proceeding to implement full scale systems using these technologies.

Prepared Solid Waste As A Supplemental Fuel - The City of St. Louis, Missouri, with demonstration grant assistance from the Environmental Protection Agency, is producing a dry, shredded solid waste fuel which is being used to supplement pulverized coal in an existing Union Electric Company suspension fired boiler.[8] Solid waste fuel provides 10 percent of the energy used in the boiler. At this rate, the 125 megawatt boiler is capable of burning 350 tons of prepared solid waste fuel per day. The project engineers are experimenting with increasing the solid waste fuel to 20 percent of the boiler feed.

The process is divided into two distinct operations - preparation firing. A fuel transportation system is also required in St. Louis because the fuel is prepared 18 miles from the power plant. At the processing plant (Figure 1) municipally collected solid waste is shredded in a horizontal hammermill and fed into an air classifier which separates the material into heavy (dense) and light fractions. The heavy fraction is passed over a magnetic belt to remove ferrous metals. The light,

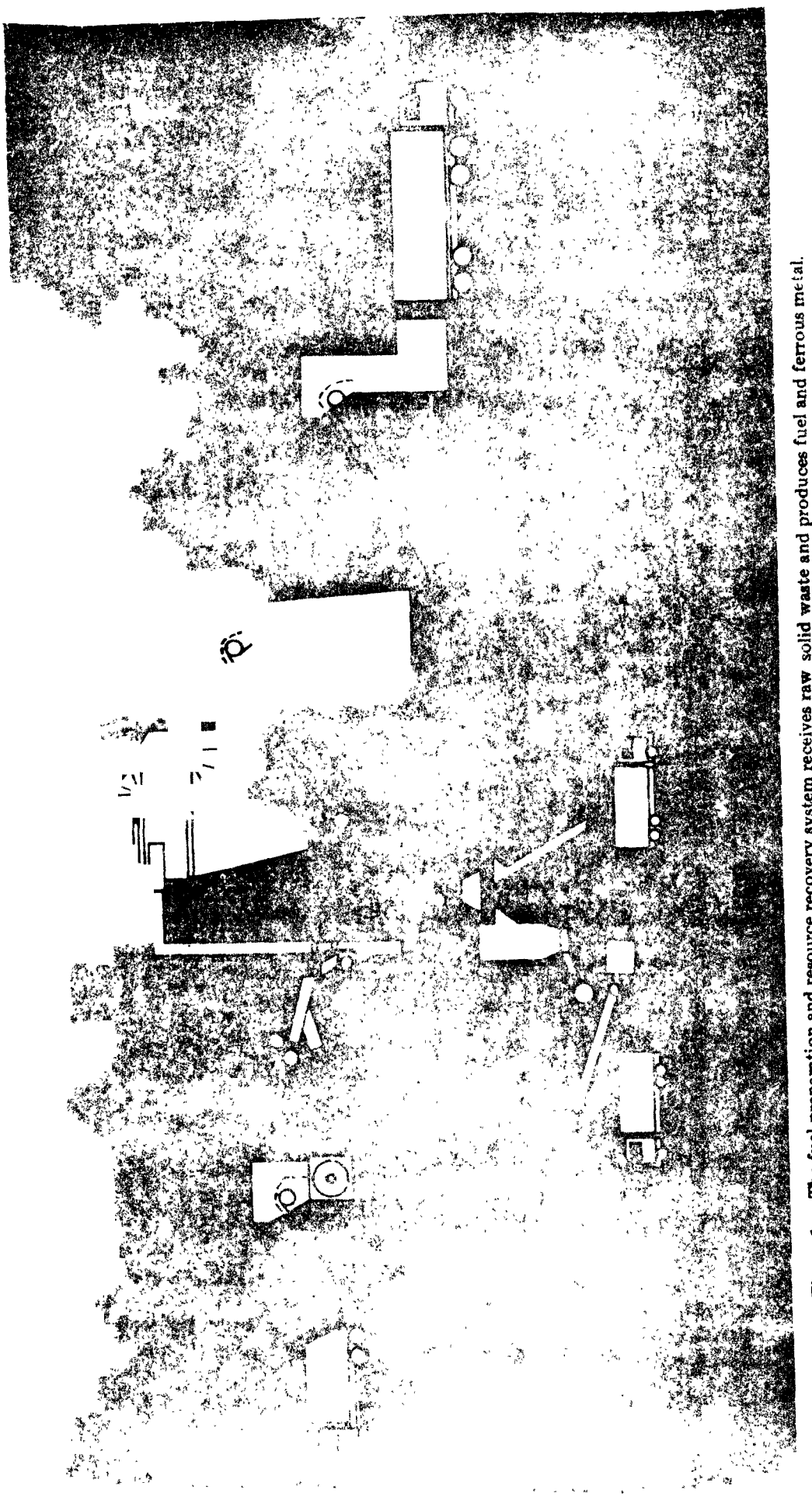

Figure 1. The fuel preparation and resource recovery system receives raw solid waste and produces fuel and ferrous metal.

mostly combustible material is stored temporarily in a bin and is then transferred to 75 cubic yard transfer trailers for the trip to the power plant. At the power plant (Figure 2) the prepared fuel is transferred to a smaller bin from which it can be pneumatically blown into the boiler.

Although still under investigation, similar systems are already being implemented in several other communities. In Ames, Iowa a prepared fuel will be used in a municipally owner power plant[9], and in Chicago it will be used by the Commonwealth Edison Company.[10] In East Bridgewater, Mass., Combustion Equipment Associates is preparing a solid waste fuel for use by the Weyerhaeuser Company.[11] The Union Electric Company has announced a 70 million dollar program to expand its demonstration operation to serve the entire metropolitan St. Louis area.[12]

Other studies are considering the use of this fuel as a supplemental fuel in oil-fired boilers, preparing the fuel using a wet pulping method developed by the Black-Clawson Company, and pellitizing the fuel so that it can be used in grate-fired boilers.

Pyrolysis - pyrolysis is the thermal decomposition of materials in the absence or near absence of oxygen. The high temperature and the "starved air" situation in the pyrolysis of solid wastes results in a breakdown of the materials into three parts: (1) a gas consisting primarily of hydrogen, methane and carbon monoxide; (2) an "oil" that is liquid at room temperature and includes organic chemicals such as acetic acid, acetone and methanol; (3) a char consisting of almost pure carbon, plus any glass, metal, or rock that may have been processed. The design of the individual system controls which of these outputs will be the predominant "product"[13]

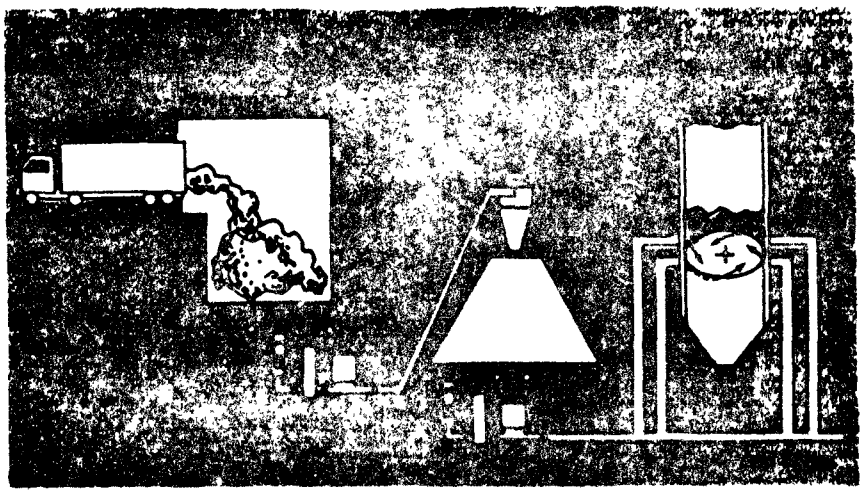

Figure 2. The solid waste fuel is delivered to the power plant and is fired pneumatically into the boiler.

There are currently two systems under development which show promise of producing a fuel of sufficient quality and yield as to be marketable. A liquid fuel is to be produced in the Garrett Research and Development Company's "Flash Pyrolysis" system undergoing EPA demonstration in San Diego County, California.[14] A gaseous fuel is to be produced in a Union Carbide System being tested by that company in S. Charleston, West Virginia.[15]

Oil Pyrolysis - The demonstration plant being built in San Diego County, California will produce an oil-like, liquid fuel which will be used by the San Diego Gas and Electric Company as a supplemental fuel in an existing oil-fired boiler. This fuel, which is produced at the rate of 1.0 barrels per ton of solid waste, has a heating value of about 94,000 BTU per gallon. This is about 65 percent of the heating value of No. 6 fuel oil, on a volumetric basis. This oil has a higher moisture content and a higher viscosity than No. 6 oil.

The Garrett Process, for which a flow diagram is shown in Figure 3, consists of a complex "front-end" preparation system followed by a relatively simple pyrolysis reactor. To prepare the solid wastes for the reactor it must first be shredded. An air classifier then separates out a light combustible fraction, which, after being dried, is shredded again; this time to a particle size of 1/16th of an inch. This material, now resembling "vacuum cleaner catch," is then introduced into the reactor where it is mixed with hot glowing char in an inert atmosphere. In less than a second, and at a temperature of 900°F the material is pyrolyzed. As the char-gas mixture comes out of the reactor the char is separated for reuse within the reactor and the

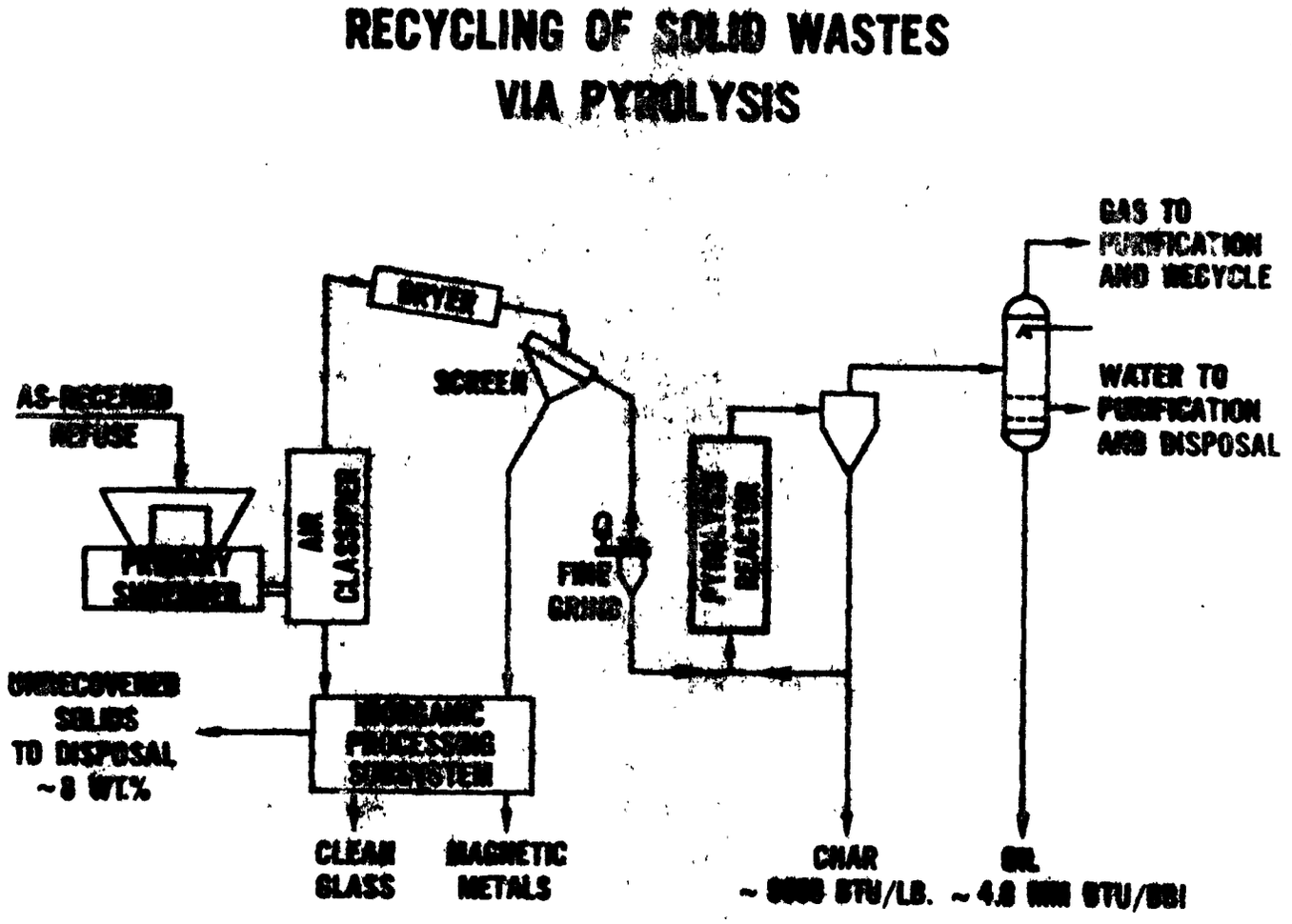

Figure 3. The "Garrett" process produces an oil-like liquid fuel from solid waste.

gases are quenched to recover the oil. The process char is recirculated as the energy source to pyrolyze the incoming material.

Gas Pyrolysis - A gaseous fuel product is being generated by a process under development by the Linde Division of the Union Carbide Corporation. This company is currently constructing a 200 ton per day test facility at its plant in S. Charleston, W. Virginia.

The key element of the system is a vertical shaft furnace. As depicted in Figure 4, refuse is fed into the top of the furnace. Oxygen entering at the base of the furnace reacts with the char formed from the refuse. This reaction generates a temperature in the hearth high enough to melt and fuse the metal and glass. This molten metal and glass drains continuously into a water quench tank forming a hard granular material.

The hot gases formed by reaction of the oxygen and char rise up through the column of refuse and pyrolyze the refuse. In the upper portion of the furnace, the hot gas also dries the incoming refuse. The gases exit the furnace at about 200°F. The exhaust gas contains considerable water vapor, some oil mist and minor amounts of undesirable constituents. These components are removed in a gas-cleaning system.

The resultant gas is a clean burning fuel comparable to natural gas in combustion characteristics, but with a heating

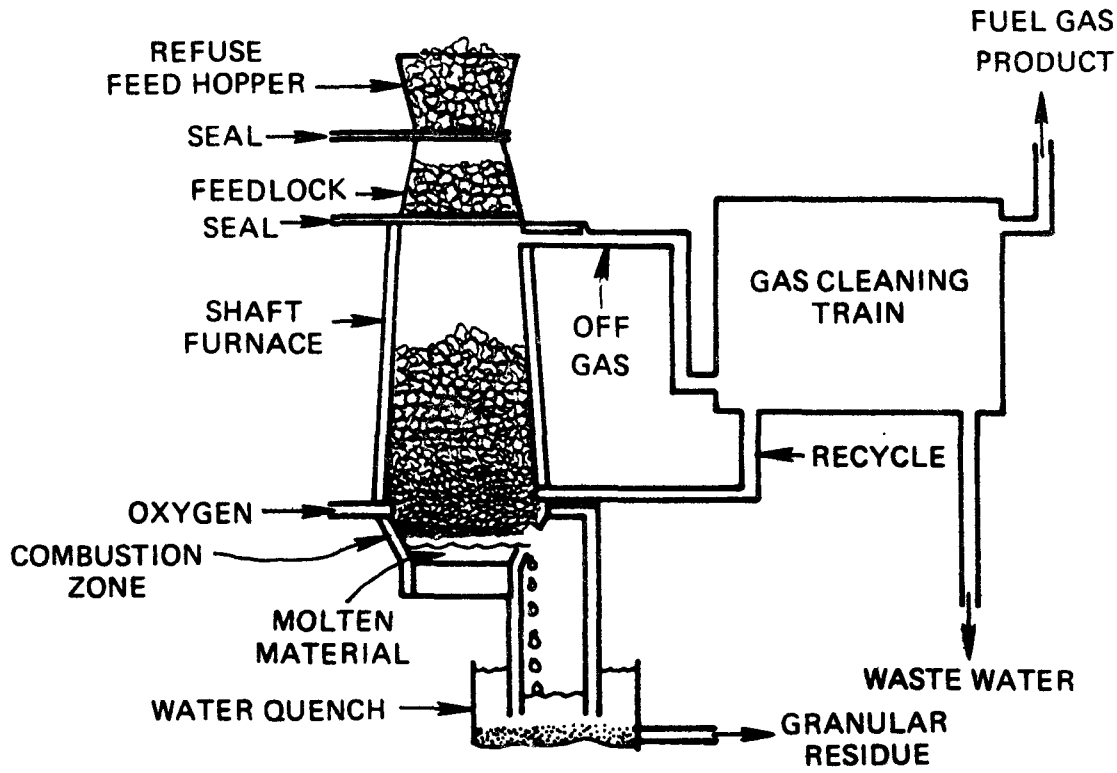

Figure 4. The key element of the Union Carbide process is a vertical shaft furnace.

value of about 300 BTU/cubic foot. It is essentially free of sulphur compounds and nitrogen oxides. It burns at approximately the same temperature as natural gas. This gas can be substituted for natural gas in an existing facility. The only plant modification would be enlarging the burner nozzle so that the volumetric flow rate can be increased.

One limitation on use of this gas is the cost of compressing it for storage and shipment. Compression costs per million BTU's of gas will be 3.1 times greater than for natural gas. This is because it requires a larger quantity of this gas to yield the same amount of energy as natural gas. As a result, markets for this gas will have to be within 2 miles of the producing facility and only short term storage can be contemplated.

Methane Production - When solid waste decomposes in an anaerobic (oxygen-free) environment, it produced methane and carbon dioxide. Programs are currently underway to recover methane produced from the natural decomposition of solid waste in a sanitary landfill[16, 17] and from the accelerated decomposition of solid waste in a mechanical digester, such as is used to digest sewage sludge.

In the sanitary landfill recovery program a well is drilled through the fill and lined with perforated pipe. The gases are pumped out of the fill and then cleaned of the carbon dioxide using membrane filtration or cyrogenic separation techniques. The NRG NuFuel Company is installing gas recovery systems in landfills operated by the County of Los Angeles and the city of Phoenix. Both of these sites possess very specific characteristics which are

necessary if the concept is to be feasible.

The National Science Foundation is currently supporting a research effort by the Dynatech Corporation to examine the feasibility of combining solid waste with sewage sludge for digestion in a mechanical digestor.[18] Pipeline quality gas would be recovered at the rate of 3,700 cubic feet of 900 BTU gas per ton of solid waste.

STEAM & ELECTRICITY

Conventional Uses of Steam

Steam can be thought of as the transportation system in an energy network. The chemical energy of the fuel is transported by the steam as thermal energy to the user where it is converted to mechanical energy.

In a steam electric power plant a fuel is burned in a furnace enclosed in walls constructed of tubes filled with water. Heat, released by the burning fuel, converts the water to steam. The steam is then piped to a turbine where it gives up it's heat energy by driving a generator which produces electricity. Due to practical limitations on the efficiency with which heat can be transferred to the steam and can later be extracted from it, about 10,000 BTU of fuel energy are required to produce one kilowatt-hour (kwh) of electricity having 3,412 BTU of energy.[19]

Steam temperatures generally range from 250°F to 1,050°F and pressures range from 150 pounds per square inch (psi) to 3,500 psi. The limitations placed on temperature and pressure are the strength of the materials used to construct the system. In electric power plants the greatest efficiency is achieved at the highest temperatures and pressures. In steam distribution systems temperatures are kept as low as possible to minimize heat loss in the delivery system and pressures are kept as low as possible to reduce the cost of the system and minimize danger from bursting pipes.

In systems that use solid waste as the sole or primary fuel, the steam is usually produced at 600 pounds per square inch or less in order to minimize slagging and corrosion of the boiler tubes. The steam can be further processed in separate units to bring it to the pressure at which it will be used.

Marketability of Steam

Unlike fuels derived from solid waste, steam produced from solid waste is indistinguishable from steam from any other source.

To be marketable this steam must meet the specific needs of the user. When designing a solid waste disposal/steam recovery system some factors which must be considered are:

a. Proximity to Customer - The facility must be close enough to economically serve the steam market. Steam can only be transported about 2 miles, and in congested areas, expensive pipe line installation problems may further restrict this distance.

b. Value - The cost at which the steam is delivered must be competitive with the costumers alternate energy sources.

c. Quantity - The amount of steam supplied must be compatible with the customers needs. If peak loadings cannot be supplied entirely by burning refuse then standby, fuel-fired boilers will be needed.

d. Operating Schedule - The steam producing facility must be set up on an operating basis which satisfies the operating schedule of the steam customer.

e. Availability of Refuse - The municipality must insure that it has enough refuse to meet the steam output commitments.

f. Steam Quality - The temperature and pressure at which the steam is produced must be a function of both the optimal performance of the unit and the limits acceptable to the customer.

g. Reliability - The system must include sufficient back up facilities to meet the level of reliability of supply agreed upon. This may include contingency plans to burn fossil fuels when the flow of solid waste is interrupted and standby boilers for use when the solid waste unit is out of service. The cost of building and operating these facilities must be considered in the economic evaluation of the system.

h. Excess Steam - The facility must be designed to serve the communities disposal needs, even if there is an interruption to the steam market. Condensing units or a backup sanitary landfill may be necessary.

i. Timing - The steam must be available when it is needed. Unanticipated delays in construction of the facility could force a steam customer to find another source of steam.

Steam can be marketed in two ways - as a make-up to another system which can carry the entire load, if necessary, or as a primary supply source. This would be analagous to how natural gas is sold on either an interruptable or noninterruptable basis.

As make-up-steam, the customer carries the burden (an additional cost) of supplying standby equipment and labor to produce additional steam if needed. This lowers the value of the steam, but also reduces the risk and responsibliity that the municipality must assume. The value of the steam would be limited to the value of fuel saved by the customer.

If on the other hand, the municipality is supplying steam which the customer does not otherwise have the capability of producing, then the municipality must guarantee the reliability of the supply. Although the municipality's costs will go up, the value of the steam will also go up. The steam would now have a value equivalent to what the customer would have to spend to produce it himself.

Market Opportunities for Steam

Most metropolitan areas have one or more major outlets for steam. Yet, despite the fact that proven technology exists for generating steam from municipal solid waste, constraints to its use has made the marketing of the steam a very difficult task.

District Heating & Cooling Systems - There are about 450 commercial and campus district steam heating systems operating in this country.[20] Many of these systems also distribute chilled water for cooling buildings during warm weather. Table 2 lists some of the cities which have steam systems serving their central business or industrial areas. The fuel crisis has also encouraged other cities to consider such systems in an effort to make more efficient use of limited, and increasingly more costly fuels.

TABLE 2

SELECTED CITIES SERVED BY DOWNTOWN HEATING/COOLING LOOPS*

Akron, OH.	Hartford, CN.
Allentown, PA.	Houston, TX.
Atlanta, GA.	Indianapolis, IN.
Baltimore, MD.	Los Angeles, CA.
Birmingham, AL.	St. Paul, MN.
Boston, MA.	Nashville, TN.
Cheyenne, WY.	New York, NY.
Cleveland, OH.	Oklahoma City, OK.
Dayton, OH.	Omaha, NB.
Denver, CO.	Philadelphia, PA.
Detroit, MI.	Pittsburg, PA.
Eugene, OR.	San Diego, CA.
Grand Rapids, MI.	Seattle, WA.
Harrisburg, PA.	Tulsa, OK.

*International District Heating Association. 1973 Rate Reference Book. Pittsburgh

Steam is distributed at a low pressure, generally in the neighborhood of 250 pounds per square inch, which can be easily provided by a solid waste disposal facility. Unlike the demand for electricity, which has certain peak periods, steam demand is fairly constant throughout the day and from day to day. Seasonal variations can be significant, but if the utility also distributes chilled water it can operate its chilling plant with a steam-driven turbine. In any event, steam demand can be sufficient to accomodate a constant amount of steam produced in an energy recovery plant during most, if not all, of the year.

Because steam cannot be transported for more than about two miles, the solid waste plant must be located close to the steam users. This will usually mean the central part of the city. Although land costs may be higher, solid waste hauling costs should

be minimized, because of the proximity of the plant to the waste generators.

Steam produced in a solid waste disposal facility could be sold to a district heating utility. The value of the steam to the utility would be equivalent to the price it would pay for the amount of fuel needed to produce the steam. However, if by purchasing this steam, the utility is able to expand its service to customers whom it previously lacked the capacity to serve, then the steam would have a higher value equivalent to the utility's own cost for producing steam.

In cities where no steam distribution network exists, the municipality can consider the installation of a complete solid waste steam generating incinerator and the steam distribution network. To minimize the costs, this could possibly be tied to a major urban renewal project or the construction of a large industrial park or complex. Although the municipality would then be able to sell the steam at a much higher price, it would also be responsible for a much higher capital investment. Because it would be the only source of supply for its customers, it would also have to assume the responsibility for total reliability. A back-up system would be needed to provide steam when the incinerator was out of service or if there was an interruption in the delivery of refuse to the facility.

There are two systems currently being constructed that will produce steam for utility distribution. The first system, being built in Baltimore, Maryland with grant assistance from EPA, will produce steam for sale to the local utility.[21] The utility will use the steam in its existing steam distribution loop. Revenue

from the sale of steam will amount to at least $3.50 per ton of refuse.

In the second project, the city of Nashville created an independent, non-profit authority, which will sell steam and chilled water to commercial and government office buildings in downtown Nashville, using refuse-fired waterwall incinerators as the primary steam source.[22] Fossil-fuel-fired, back-up boilers will also be available. Steam revenues will generate $10.00 per ton of refuse. This price, nearly three times that being paid for Baltimore's steam, reflects the cost of the complete steam generation and distribution system. Chilled water, which is solid at a much higher price, will provide an even greater amount of revenue - about $25.00 per ton of refuse.

Industrial Plants - Large inustrial facilities such as paper mills, food processers and major manufacturing plants are also steam customers. Industrial customers which operate their facilities 24 hours per day are preferred because a waterwall incinerator is designed for around-the-clock operation. Some industrial users may place specific constraints on the quantities of steam to be delivered at certain given times and will most likely want to specify temperature and pressure. These factors must be identified and incorporated in the design of the incinerator.

Although it is impossible to predict the long term effect of the energy crisis on industrial needs, fuel shortages should improve the marketability of a reliable steam supply.

Many cities have single industries large enough to utilize all the steam that would be produced from a large solid waste facility. In Saugus, Massachusetts a 1,700 ton per day waterwall incinerator is being built. All of the steam produced in this plant (about 350,000 pounds per hour) will be used in an adjacent General Electric Company Plant for heating and cooling, electric power generation and a variety of manufacturing and testing operations.[23]

Steam Electric Power Plants - Although steam electric power plants use tremendous quantities of steam it may be difficult to develop satisfactory marketing arrangements in this sector.

The costs of accomodating an outside steam source may exceed the value of the expected fuel savings. Modification of the pressurized components of the power plant could involve costly construction operations and could require that the power plant be kept out of service for a lengthy period of time. Also, a boiler cannot be

be operated at the same efficiency* both with and without the supplemental steam. For one of the two modes additional fuel will be needed to obtain the same energy output.

The total amount of electricity (demand) that a utility must produce varies considerably throughout the day and from day to day. The utility's most efficient plants are used continuously to supply the minimum demand (base load) on the system while the less efficient or otherwise more costly plants are used to supply the peak demands. Thus each power plant within a utility system, and in fact, each boiler within each plant will have a different rate of utilization (load factor) depending on its relative operating efficiency. The utility would only be able to buy steam when the outfitted boiler is "on-line". This would be 75 percent or more of the year for a base load unit, but could be 25 percent or less for a peak loaded unit.

One way to overcome the problems of retrofitting an existing unit would be to build a new base load superheater and turbine -

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*Efficiency - Each power plant requires a certain number of BTU's of fuel to generate 1 kilowatt hour (kwhr) of electricity. The less fuel needed, the more efficient is the plant. One kilowatt hour equals 3,412 BTU's but the maximum difference between the safe operating temperature of the power plant and the temperature at at which heat can be discarded to the environment, limits power plant efficiency to a maximum of about 40 percent. Therefore the most efficient steam electric power plants require about 8,500 BTU's per kwhr. Most modern power plants use about 10,000 BTU's per kwhr (33 percent efficiency).

generator set especially to take steam produced in the solid waste facility. The Florida Power and Light Company, in seeking an arrangement whereby it could purchase energy from a planned facility in Dade County proposed such an arrangement.[24] The generating facility would be built by the company building the solid waste facility, but it would be "bought" by Florida Power & Light. Florida Power and Light would then buy the steam and also pay for the facility on a "units of electricity produced" basis. This requires capital investment by the municipality and increases the financial risk because reimbursement is tied to production.

Systems for Producing Steam

Systems available for the generation of steam from solid waste include waste heat boilers, waterwall incinerators, and refuse-fired support boilers.

Waste Heat Boilers - In addition to their use in many industrial processes, waste-heat boilers have been used in the early design of heat recovery incinerators in this country. The boiler package is placed in the flue following the secondary combustion chamber of a conventional refractory lined, mechanical grate incinerator. The poor operating characteristics of refractory lined incinerators has made this approach obsolete.[25]

A waste heat boiler is employed quite effectively, however, in a new system currently being built in Baltimore, Maryland.

In this plant, which was designed by Monsanto, the boiler follows a pyrolysis kiln. The main components of the system are shown schematically in fig. 5. Heat cannot be recovered from the kiln directly because it is used to accomplish the pyrolysis of the solid waste. Once the pyrolysis gases are formed they are combusted in a separate afterburner and the heat that is released is then recovered as steam using a package type, waste heat boiler. Two hundred thousand pounds per hour of steam will be recovered from the processing of 1,000 tons of solid waste per day. The steam will be transmitted 3/4 of a mile, by pipeline, to an existing steam distribution system which is operated by the local utility.

Waterwall Incinerator - Current incinerator design practices have almost entirely replaced the refractory lined combustion chambers with waterwall furnaces. This type of construction consists of furnace walls constructed of vertically arranged metal tubes joined side-to-side with metal fins. Radiant energy from the burning of refuse is absorbed by water passing through the tubes. Additional boilers packages, located in the back passages of the incinerator, control the conversion of this water to steam of a specified temperature and pressure. By transferring the heat released by combustion to the water, the volume of air needed to keep the operating temperature of the incinerator at an acceptable level is reduced. This in turn reduces the size of the unit and its air pollution control equipment. In fact, the volume of gas entering the air pollution control equipment will be only 25 percent that of an air-cooled, refractory unit. So effective is this means of temperature control that this type of construction has become standard even in incinerators not having heat

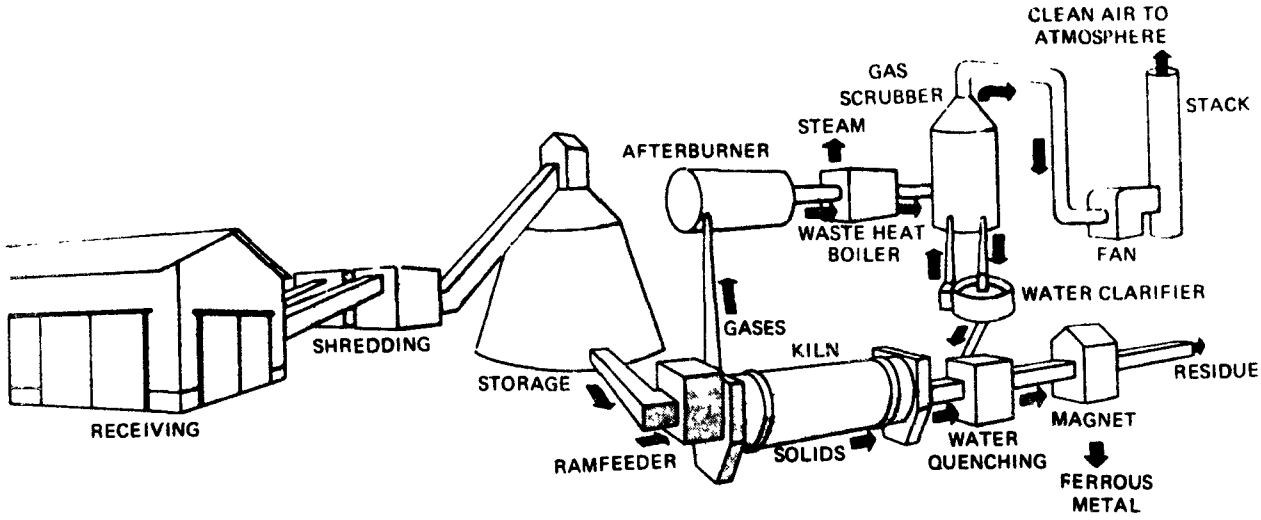

Figure 5. The Monsanto system recovers steam following the pyrolysis of municipal solid waste.

recovery provisions.

Refuse Fired Support Boilers - In Europe many municipalities combine waterwall refuse units with separate fossil fired boilers in one facility.[26] Steam from the two separate units is integrated to drive one turbine/generator system. This arrangement is shown in fig. 6 where the unit on the left is a refuse fired boiler and the one on the right is coal fired.

One reason this concept is widely used in Europe, but not presently used at all in this country is that unlike this country, many European municipal governments are responsible for solid waste disposal, power generation, distribution of steam for district heating and the operation of electrically powered transportation systems.

Markets for Electricity

Like steam, electricity produced from solid waste would be indistinguishable from electricity produced by any conventional method. The problem in marketing electricity, though, is that it can only be marketed to the electric utility serving the area, because within that service area the utility is generally exempt from competition. The only exception to that would be where the utility is municipally owned, but this amounts to only 10 percent of the nations generating capacity.[27]

The price that a utility will pay for electricity will depend upon whether it is used to satisfy base load or peak load demands. Although peak load marketing will command a much higher price, a municipality would need to sell electricity on a continuous basis (i.e. as base load) in order to maintain a continuous solid waste disposal operation.

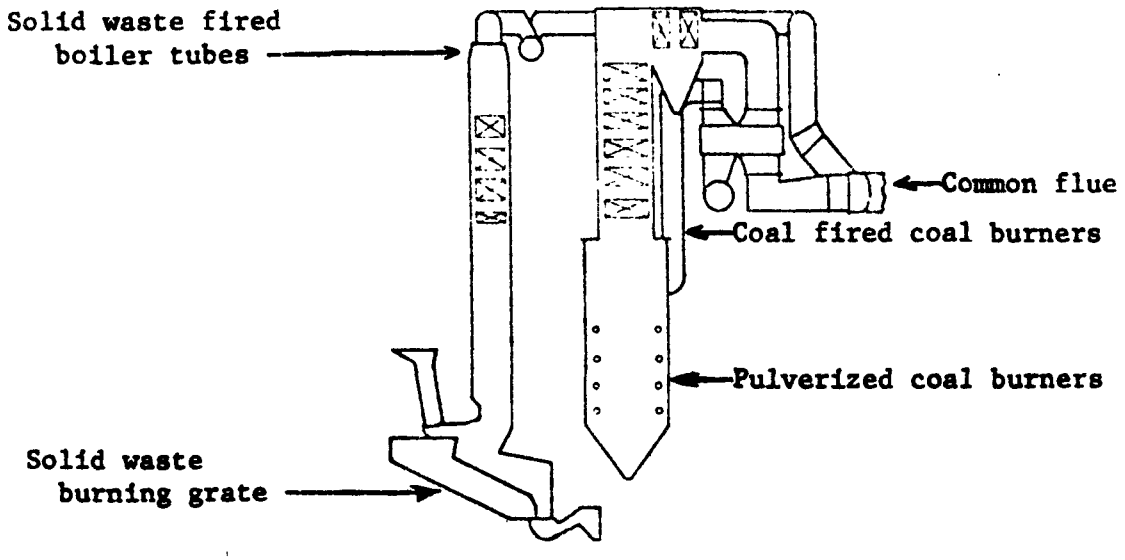

Figure 6. **Separate solid waste and coal-fired boilers produce steam for one turbine.**

A municipality considering the sale of electricity to a utility should seek to establish a floating price for the electricity whereby the price would rise as the demand on the utility increased. The price would then be a function of the incremental direct costs the utility would incur in producing the additional electricity.

Systems for Producing Electricity

The fuel and steam producing systems discussed earlier can be expanded to include power generation. An economic analysis would have to be undertaken to determine if the revenue produced from the sale of the electricity would be enough to offset the additional capital and operating costs of the equipment.

The direct generation of electricity is being explored through a research project funded by the Environmental Protection Agency.[28] Starting from a basic concept, the Combustion Power Company has developed a completely integrated solid waste combustion - power generation system. Current efforts invlove the shakedown of a 100 ton per day pilot plant.

Incoming municipal refuse is shredded and air classified to remove noncombustibles. Metal and glass are further separated for recovery. The combustible fraction is pneumatically transported to an intermediate storage facility and from there into a pressurized fluid bed combustor. The hot, high pressure gases from the combustor pass through several stages of air cleaning equipment to remove particulates. The cleaned gases are then expanded through a gas turbine that will generate 1,000 KW of electricity. Although the pilot plant operates at only 45 PSIG, commercial plants would operate at pressures in excess of 100 PSIG. A schematic of this system is shown in Figure 7.

Performance problems which have caused accelerated deterioration of the turbine blades have slowed the development of this process. This

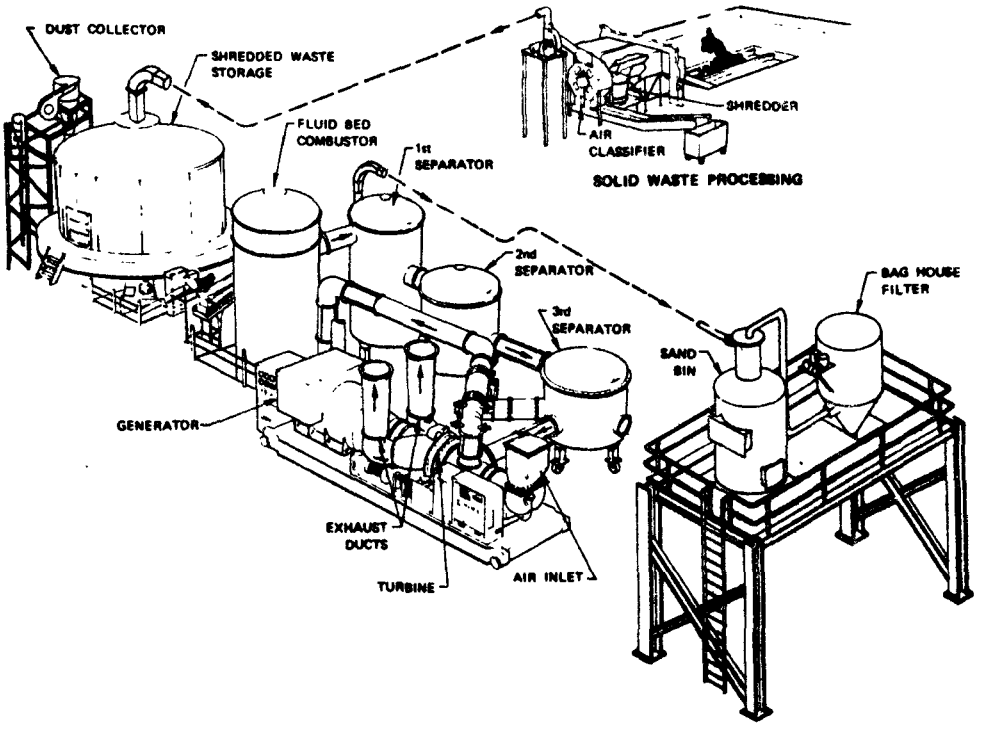

Figure 7. The CPU-400 produces electricity from the combustion of solid waste in a high pressure fluidized bed.

and other problems must be solved before this is a technically and economically feasible system for energy recovery.

ANALYSIS AND CONCLUSIONS

The key to sucessful implementation of a solid waste energy recovery program is selecting a system which is compatible with the energy market as well as the community's solid waste disposal requirements. Once a suitable market has been identified, an appropriate system can be designed which will convert the solid waste energy potential into a marketable form.

Comparison of Market Opportunities

The most important characteristics of the market for solid waste produced fuels and energy are that it be large and that it be favorably located. The size of the market is very important because the customer may have to absorb the cost of process changes needed to accommodate the new energy source. This is particularly true when producing an oil or dry prepared fuel because special storage and firing facilities are needed, and these fuels would only be fired as a small percentage of the total fuel load.

Steam and gas can only be transported very short distances and although the dry and liquid fuels can be transported farther transportation costs should be minimized wherever possible. Therefore, the preferred market would be a facility located near the point of solid waste generation.

Steam electric power plants are the most obvious market to be given initial consideration. The energy value of solid waste, on a per capita basis, amounts to between 5 and 10 percent of the per capita use of fossil fuels for electric power generation. The multiplicity of plants comprising

most utility systems increases the probability that an acceptable market can be found.

Steam distribution systems are also a good prospective market. The rising cost and scarcity of fuels is even creating a demand for new or expanded systems. These systems are centrally located in order to serve the greatest concentration of customers, so haul distance would be minimized. There is less fluctuation in load than in electric power plants, and the lower operating temperature and pressure is compatible with the constraints of a refuse fired system.

Comparison of Fuel Types

The key to marketing energy from solid waste is producing an energy form that can be sold and used without consideration to the fact that it is derived from solid waste. In addition, the type of fuel produced should be storable and transportable so that the solid waste facility can be built and operated independently of the fuel market.

Steam and electricity satisfy the first objective, but neither can be stored and steam can be transported only very short distances.

The solid and liquid fuels can be transported and can even be stored for brief periods of time (several days to several weeks). However, both fuels require the user to install special storing and firing facilities. In addition, the user must follow special handling procedures to minimize problems of air pollution and corrosion.

Gaseous fuels are less likely to require special handling or need separate facilities for storage and firing, but those currently being produced cannot economically be compressed for extended storage and shipment. The best of the gaseous fuels cannot be shipped more than two miles.

Comparison of Technological Alternatives

Municipalities require solid waste disposal systems that are operationally

reliable and involve a minimum of technical risk. Futhermore, the system must do an environmentally acceptable job at an economic cost - although not necessarily at the least possible cost.

Risk and reliability are usually evaluated through examination of existing, full size systems in actual operation. A number of energy recovery systems which are currently being proposed to cities, however, have not had this long term operating experience. These systems have generally been developed by private companies which hold patent rights to the process. Risks of procurement of such systems can be reduced by "turn key" solicitations subject to detailed performance specifications.

Municipalities can also minimize risk and avoid large capitol investments by entering long-term contracts for private ownership and operation of the solid waste disposal/energy recovery system.

Waterwall incinerators are already in widespread use in this country. While there is little risk of technical failure, the long-term reliability of these systems has not yet been established. Waterwall incinerators are usually the most costly of the energy recovery systems, on both a capitol cost and operating cost basis.

The 1,000 TPD pyrolysis - steam recovery system in Baltimore will be in full operation in late 1974. It is being built under a turn-key, fixed price contract with guarantees on the daily throughput, amount of air emissions and extent of burnout.

The system expected to be the least costly of the energy recovery options is the use of dry shredded waste as a prepared fuel. One full size plant has been in operation for over two years and several others are presently under construction. This system has been particularly attractive because energy can be recovered with a minimum amount of processing.

Both oil and gas recovery through pyrolysis, and direct conversion to electricity are undergoing demonstrations at less than full size. Another generation of hardware will be needed before widespread utilization can be expected.

The only energy recovery options available now are waterwall incineration and prepared refuse fuel systems, although neither has been completely evaluated. Steam recovery through pyrolysis should follow closely behind there, but the other options will not be ready for full scale use until the late 1970's. Some acceleration of this can be expected if the companies producing the systems assume the development risk through direct ownership of the facility or by offering them initially on a "no-risk" basis.

Selecting an Alternative

Implementing a solid waste energy recovery program is for more complex than just selecting a technology. It first, and above all else, requires securing a reliable and realistic market.

All aspects of the market must be carefully understood by both the user of the fuel or energy and the municipality supplying it. The constraints of the market will then indicate the technical alternatives available. Table 3 highlights the various major markets for solid waste energy and the possible energy forms that can satisfy those markets. Selecting a technology will then be narrowed to just one or a few alternatives. The final selection of a system will depend on the status of its availability, and thus it's relative risk, and the estimated net operating cost.

TABLE 3

MARKETS FOR SOLID WASTE ENERGY

Fuel Uses		Solid Waste Energy Form				
Conventional Energy Source	User	Steam	Prepared Fuel	Liquid Fuel	Gas	Electricity
Coal	-Industrial Boilers and Furnaces	x	x	x	x	
	-Power Plants*		x	x	x	
Gas	-Residential and Commerical Heating	-	-	-	-	
	-Industrial Boilers and Furnaces	x	-	-	x	
	-Power Plants*		-	-	x	
Oil	-Residential and Commerical Heating	-	-	-	-	
	-Industrial Boilers and Furnaces	x	-	x	x	
	-Transportation	-	-	-	-	
	-Power Plants*		-	x	x	
Electricity	-Utility Distribution					x
	-Industrial Plants					x
	-Municipal Lighting					x
	-Mass Transit Systems					x
Steam	-Utility Distribution	x				

*Electric or steam utility plants.

APPENDIX A - ENERGY DEMAND

In examining the prospects for marketing solid waste fuels, it is helpful to review the forms and uses of conventional fuels. Total energy demand in the U. S. in 1970 was 67.8 quadrillion BTU's.[29] This is equivalent to 32.5 million barrels of oil per day.* This energy is supplied by three major fossil fuel sources-oil, coal, and gas; and by hydroelectric, geothermal, and nuclear power. Transportation, industrial operations and residential-commercial users account for the major uses of energy. The matrix in figure 8 shows the relationship between energy sources and uses.

Coal

Coal has been the staple of American energy supply. In addition to its abundance, coal is the cheapest source of energy currently available. Unfortunately, when coal is burned its high sulfur and ash contents contribute to air pollution control problems. Other environmental problems associated with a major percentage of our coal result from strip mining and the subsequent release of acid-mine drainage. Coal's predominant use in this country is in large industrial and utility furnaces or boilers where the cost of adequate air pollution control equipment can be economically absorbed. The BTU content of American coals range from 11,000 to 14,000 BTU/lb.

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*Calculated by converting the energy produced from the other fuel forms to the equivalent amount of oil needed to obtain the same amount of energy.

Oil

In 1970 the U. S. consumed 13.9 million barrels of oil per day. Of this, 3.5 million barrels were imports. All further increases in oil consumption are also projected to come from imports, mostly from the Middle East.[30] With this supply having become politically vulnerable, new sources of oil will be needed to satisfy our increasing demand.

Crude oil is processed, by various refining operations, into more than 100 different products. The lighter (lower density) fuels are gasoline, diesel fuel and jet fuels. These fuels are characterized by good vaporization and burning properties, low quantities of impurities and good storage stability. They account for better than 50 percent of the liquid fuel market and are utilized primarily for transportation.

Fuel oils are heavier than the fuels used for transportation and are required to meet less stringent performance and quality characteristics. These fuels are graded from No. 1 to No. 6 with the higher numbered grades having higher viscosities and lower purity requirements. Grade Nos. 5 and 6 which require pre-heating facilities for pumping and storing the fuel, are used in large industrial boilers and furnaces where additional costs for handling and firing facilities can be accomodated. The heating value of liquid fuels varies from 110,000 to 150,000 BTU/gal, with the heavier fuels having the higher BTU contents.

Gas

The demand for gaseous fuels currently exceeds the available supply. Gas is a particularly popular fuel because price regulations make it cheaper than most other fuels It is easily stored, shipped, and fired,

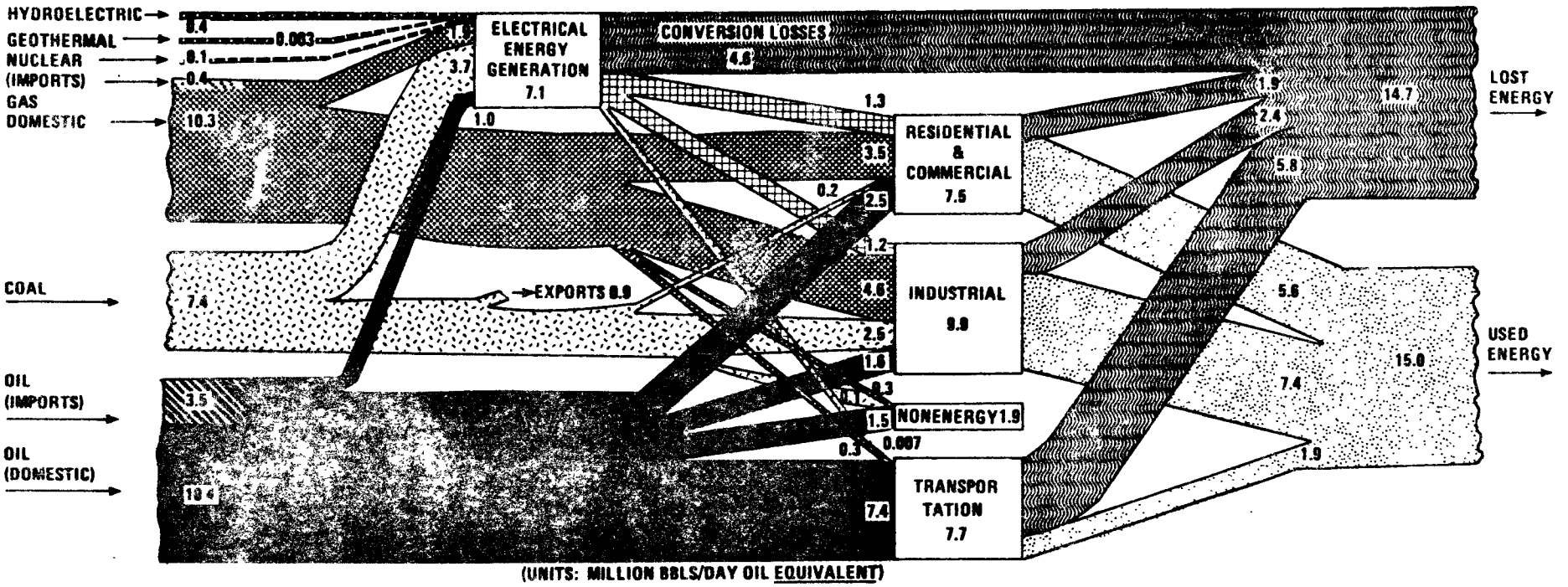

Figure 8. Energy supply and consumption, 1970.[2]

and it burns essentially pollution free.

The major gaseous fuel is natural gas, which is an odorless, colorless gas that accumulates in the upper part of oil or gas wells. It consists chiefly of methane, and has a heating value between 1,000 and 1,100 BTU/cu. ft.

Propane, and butane are produced in the process of refining petroleum. Their heating values are considerably higher than natural gas. Because they are easily liquidfied under pressure they are usually "bottled" in steel cylinders or shipped in large bulk-type pressurized tanks. They are used either as standby supplies for users of natural gas or as fuel for stoves, trucks, buses, etc.

There are also many types of manufactured gas which are produced by heating various solid fuels under specifically controlled conditions. These gasses are referred to as coal gas, coke-oven gas (or coke), producer gas, blast-furnace gas, water gas, etc. The heating valve of these gases ranges from 100 to 750 BTU/cu. ft. In many instances they are used by the industry producing them, because their heating valve is low, and it is not generally economical to compress them for shipment or storage.

Electrical Generation

The electric utility industry is both a supplier of energy to consumers and at the same time, is itself a major consumer of fuels. In fact, in 1970, 25 percent of the energy used in the U. S. was consumed by the electric generating industry. More than half of this fuel input came from coal, with gas making up 24 percent and oil 15 percent. Nuclear energy supplied only 2 percent of the industry's needs in 1970. Although nuclear generating plants are expected to supply 53 percent of the total utility load by 1990, the use of coal and oil is also projected to increase during that time period, but at a less rapid rate.

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SOLID-WASTE-AS-FUEL SYSTEMS

Prepared solid waste can be used as a low sulfur supplementary fuel for existing steam or steam-electric coal or oil-fired boilers. The concept is currently being demonstrated by the City of St. Louis, Union Electric Company and the U.S. Environmental Protection Agency.

As a result of the St. Louis demonstration, many cities and electric utilities have expressed significant interest in investigating the local feasibility of the concept. Several systems are now in the engineering design phase and others are in the late planning stage.

Several companies are presently marketing turn-key, fixed-price design and construction contracts for solid-waste-as-fuel systems. Some of these companies are offering to finance, own, and operate the facilities, and then charge the users of the system a fixed fee per ton of waste.

Although the system being demonstrated at St. Louis and the various other systems being marketed throughout the country are not identical, they do have several steps in common:

Size Reduction

The particle size of the waste is reduced to less than one inch.

Non-Combustible Separation

The glass, metals, and other dense materials are removed to upgrade the heat value of the fuel, to reduce materials handling problems, and to recover materials for reuse where economically and technically feasible. Although termed "non-combustible," any material that will not burn completely in the boiler designated to receive the waste is usually removed by most systems. In suspension-fired boilers, for example, where dense materials quickly fall unburned to the bottom of the boiler, dense pieces of wood, plastic, rubber and leather are removed from the fuel in most systems although they are technically combustible.

Residue Disposal

The non-combustible materials that are separated from the fuel fraction and not recovered for reuse must be landfilled.

Waste Fuel Transportation

The waste fuel can be transported pneumatically or by truck, barge, or rail.

Firing

The waste fuel is usually pneumatically fired into the boiler. The boiler can be tangentially-fired, front-fired, opposed-fired, cyclone-fired, or stoker fired. Oil-fired boilers can readily accept waste fuel if they have adequate bottom ash and fly ash handling facilities.

Air Pollution Control

Tests must be run to assure acceptable air emissions. If emissions are initially unacceptable, the air pollution control equipment must be upgraded, or the fuel preparation procedures must be modified to produce a higher quality fuel, or both.

A list of companies currently offering turn-key, fixed-price design and construction contracts follows. The list may not be all inclusive and does not imply EPA endorsement. Any modifications, additions, or subtractions to the list should be addressed to:

Energy Recovery Program (AW-563)
Resource Recovery Division
Office of Solid Waste Management Programs
U.S. Environmental Protection Agency
Washington, D.C. 20460

A jurisdiction could also contract with a consulting engineering firm and general contractor to design and build such systems. The presentation of a list of firms offering turn-key contracts is not meant to imply EPA endorsement of the turn-key approach over the consulting engineer, general construction contractor approach to design and construction. Each approach has its advantages and disadvantages; the specific objectives and limitations of each project will dictate the proper approach.

COMPANIES OFFERING TURN-KEY
SOLID WASTE AS FUEL SYSTEMS

American Can Company
Americology Division
Mr. L. C. Bielicki
American Lane
Greenwich, Connecticut 06830
(203) 552-2111

Browning-Ferris Industries, Inc.
Mr. Dennis Terry
Market Director
5207 Holden Street
Fairfax, Virginia 22030
(703) 273-7676

Combustion Equipment Associates
Mr. A. H. Bellac
555 Madison Avenue
New York, NY 10022
(212) 980-3700

Garrett Research and Development, Inc.
Mr. Theodore Jonas
2009 North 14th Street
Arlington, Virginia 22201
(703) 527-8555

Peabody Galion Corporation
Dr. John Hayden
Director, Market Development
Environmental Systems
835 Hope Street
Stanford, Connecticut 06907
(203) 327-7000

Raytheon Corporation
Mr. Robert Schroeder
Missile Systems Division
Bedford, Massachusetts
(617-) 272-9300 X472

SOLID WASTE PYROLYSIS SYSTEMS

Pyrolysis is the thermal decomposition of organic materials in an oxygen deficient environment. It is distinguished from combustion or incineration in that (1) the pyrolysis reaction is endothermic (requires heat to drive the reaction) and (2) the oxygen deficient atmosphere in the pyrolysis reactor inhibits the combustion of the organic feed material, thus producing combustible gases or oil that can be used as a fuel.

The high temperatures (1000 to 3000°F) and lack of oxygen in a pyrolysis reactor result in a chemical breakdown of the waste organic materials into three components: (1) a gas consisting primarily of hydrogen, methane, carbon monoxide, and carbon dioxide, (2) a "tar" or "oil" that is liquid at room temperature and includes organic chemicals such as acetic acid, acetone, methanol, and (3) a "char" consisting of almost pure carbon plus any inerts (glass, metals, rock) that enter the process unit. Residence time, temperature, and pressure can be controlled in the pyrolysis reactor to produce various product combinations.

A list of companies currently marketing or demonstrating pyrolysis systems follows. Brief comments about each system are also included. The list may not be all-inclusive and does not imply EPA endorsement. Any modifications, additions, or subtractions to the list should be addressed to:

Energy Recovery Program (HM-563)
Resource Recovery Division
Office of Solid Waste Management Programs
U.S. Environmental Protection Agency
Washington, D.C. 20460

PYROLYSIS SYSTEMS

Oil Pyrolysis

Garrett Research and Development, Inc.

Dr. George Mallen
P.O. Box 310
LaVerne, California 90017
(714) 293-5000

Development Status

Pilot Plant. A 4 ton per day experimental plant is operating in LaVerne, California.

Demonstration Plant. San Diego County will be demonstrating a 200 ton per day plant with support from the U.S. Environmental Protection Agency; the plant is scheduled to be operating in late 1975.

Process Characteristics

Pre-processing. Substantial pre-processing is required; most non-combustibles must be removed and the waste must be shredded to a 14 mesh particle size (similar to vacuum cleaner dust).

Reactor. Flash pyrolysis reactor; the prepared waste is pyrolyzed in suspension in the reactor during the 1/2 second retention time.

Gas Condensation. The pyrolysis gases produced during the reaction are condensed to an oil-like liquid.

Auxiliary Fuel. No auxiliary fuel is required to drive the pyrolysis reaction; the carbon char residue is combusted to provide the required heat.

Energy Products

Oil. About 1 barrel of oil will be produced from 1 ton of waste; the oil is similar to No. 6 fuel oil, with about 3/4 the heat value of No. 6 oil; the oil can be used as supplementary fuel for steam or steam-electric boilers.

Gas Pyrolysis

Carborundum Environmental Systems, Inc.

Torrax Division

John Z. Stoia
641 Erie Avenue
North Tonawanda, N.Y. 14102
(716) 694-4400

Development Status

Demonstration Plant. A 75 ton per day demonstration plant has been operating intermittently since 1972 in North Tonawanda, New York, with U.S. Environmental Protection Agency support; a final report on the project should be available from EPA by Fall, 1974.

Process Characteristics

Pre-processing. No shredding is required

Reactor. The reactor is a packed bed, vertical shaft furnace; waste is fed into the top of the reactor where it is first dried, and then pyrolyzed as it slowly descends to the bottom of the reactor.

Auxiliary Fuel. Oil or gas is required to pre-heat process air to about 1500-2000 F; the air is injected at the bottom of the reactor which allows the char to combust and provide the heat to drive the pyrolysis reaction.

Slagged Residue. The heat generated also melts the metals and glass in the residue forming a slag; the slag is tapped into a water quench tank and forms a fine-grained sterile residue.

Energy Products

Fuel Gas. A combustible gas is produced with a lower heating value of about 90 STU/ft^3, about one tenth the heat value of natural gas; although the gas cannot be economically stored or transported because of its low heat value, it can be used as supplementary fuel gas in adjacent steam or steam-electric boilers.

Steam. The pyrolysis gases can be combusted on-site and the hot exhaust gases can be passed through a boiler to produce steam.

DEVCO Management Company, Inc.

Carlton Thomas
Director
410 Park Avenue
New York, New York 10022
(212) 371-9105

Development Status

Pilot Plant. A 170 ton per day pilot plant is operating in New York City.

Process Characteristics

Pre-processing. No shredding is required

Reactor. The reactor is a horizontal rotory kiln, similar to the kilns used in the cement industry.

Auxiliary Fuel. No auxiliary fuel is required; combustion of a portion of the char provides the heat to drive the pyrolysis reaction.

Energy Products

Fuel Gas. The low heat value corbustible gas produced cannot be economically stored or transported; it can be used as supplementary fuel in adjacent steam or steam-electric boilers.

Steam. The pyrolysis gases can be combusted on-site and the hot exhaust gases can be passed through a boiler to produce steam.

Mansanto Enviro-Chem Systems, Inc.

Theodor F. Buss
Sales Manager
LANDGARD Systems
800 North Lindbergh Blvd.
St. Louis, Missouri 63166
(314) 694-2384

Development Status

Pilot Plant. A 35 ton per day pilot plant was tested in St. Louis and dismantled in late 1971.

Demonstration Plant. A 1000 ton per day demonstration plant is under construction in Baltimore, Md., with U.S. Environmental Protection Agency support; the plant should be operational by early 1975.

Process Characteristics

Pre-processing. Shredding is required to produce a 3-4" particle size.

Reactor. The reactor is a horizontal rotory kiln, similar to the kilns used in the cement industry.

Auxiliary Fuel. No. 2 fuel oil is fired directly into the kiln to provide the heat to drive the pyrolysis reaction; combustion of a portion of the char provides additional heat to the reactor.

Energy Products

Fuel Gas. A combustible gas is produced with a lower heating value of about 90 BTU/ft^3, about one tenth the heat value of natural gas; although the gas cannot be economically stored or transported because of its low heat value, it can be used as supplementary fuel gas in adjacent steam or steam-electric boilers.

Steam. The pyrolysis gases can be combusted on-site and the hot exhaust gases can be passed through a boiler to produce steam.

Electricity. The steam produced can be used to generate electricity with a steam turbine.

Pyrotek, Inc.

George Moore
Vice President
1917 St. Andrews Place
Santa Ana, California 92705
(714) 835-3880

Development Status

Pilot Plant. A 2 ton per day pilot plant is operating in Santa Ana, California.

Process Characteristics

Pre-processing. Shredding is required to produce a 2-4" particle size.

Reactor. The shredded waste passes continuously through the reactor on a moving grate; heat to drive the pyrolysis reaction is supplied indirectly through the walls of the reactor

Auxiliary Fuel. No auxiliary fuel is required.

Energy Products

Fuel Gas. A combustible gas is produced with a heating value of about 375 BTU/ft^3, about one third the heat value of natural gas; although the gas cannot be economically stored or transported because of its low heat value, it can be used as supplementary fuel gas in adjacent steam or steam-electric boilers.

Union Carbide Corporation

Linde Division

Dick Paul
270 Park Avenue
New York, New York 10017
(212) 551-2077

Development Status

Pilot Plant. A 5 ton per day pilot plant is operating in Tarreytown, New York.

Demonstration Plant. A 200 ton per day demonstration plant in South Charleston, West Virginia began operation in April, 1974; the project is a test facility, rather than a commercially operated facility.

Process Characteristics

Pre-processing. No shredding is required.

Reactor. The reactor is a packed bed, vertical shaft furnace; waste is fed into the top of the reactor where it is first dried, and then pyrolyzed as it slowly descends to the bottom of the reactor; pure oxygen is injected into the bottom of the reactor to allow the char residue to combust; the heat generated drives the pyrolysis reaction.

Slagged Residue. The heat generated also melts the metals and glass in the residue forming a slag; the slag is tapped into a water quench tank and forms a fine-grained sterile residue.

Energy Products

Fuel Gas. A combustible gas is produced with a lower heating value of about 225 BTU/ft^3, about one third the heat value of natural gas; although the gas cannot be economically stored or transported because of its low heat value, it can be used as supplementary fuel in adjacent steam or steam-electric boilers.

Electricity. The pyrolysis gases can be combusted on-site and the hot expanding gases can be passed through a gas turbine to generate electricity.

Steam. The pyrolysis gases can be combusted on-site and the hot exhaust gases can be passed through a boiler to produce steam.

PYROLYSIS OF MUNICIPAL SOLID WASTE

Steven J. Levy

Introduction

Pyrolysis is the physical and chemical decomposition of organic matter brought about by the action of heat, in the absence of oxygen. In the last several years, a great deal of interest has been generated in applying this process to municipal solid waste. Many systems have been developed, and while most utilize pyrolysis as only one reaction in a multi-step process, they are commonly referred to as "pyrolysis processes."

The primary objective in developing pyrolysis systems for municipal solid waste has been to reduce the volume of wastes requiring disposal in a manner less environmentally damaging than "conventional" incineration. A second benefit, common to most systems, has been the conversion of the organic portion of the solid waste into a useable energy form. This energy will vary according to the operating characteristics of the particular system. Organic materials can be broken down into compounds which are either gases, liquids, or solids at room temperature. In some systems, the recovered fuels are of sufficient quality that they can be substituted for fossil fuels in existing off-site facilities. In other systems, the fuel is of lower quality, and the cost of transporting it cannot be justified. In such cases, the fuel can be used directly to produce electricity or steam.

There are about 10 to 12 different pyrolysis systems under development at this time. In this paper detailed discussions will be presented on three systems, each of which is currently undergoing evaluation of a commercial size unit. Those three systems are the "Landgard" developed by Monsanto, the "Purox" developed by Union Carbide and the Garrett Research and Development Company's "Flash Pyrolysis" system.

Why Pyrolysis?

Normal combustion, as in conventional incineration, requires the presence of a quantity of oxygen sufficient to allow for the complete oxidation of the organic matter. This is provided by pumping air into the furnace. Using cellulose ($C_6H_{10}O_5$) to represent the organic material, combustion occurs as the oxygen (O_2) reacts with the cellulose forming carbon dioxide (CO_2) and water (H_2O), and releasing heat. The chemical equation for this reaction is as follows:

$$(1)\quad C_6H_{10}O_5 + 6O_2 \rightarrow 6CO_2 + 5H_2O + \text{heat}$$

In order to remove the heat from the combustion chamber without damaging the incinerator, more air is pumped through the incinerator than is theoretically needed to complete the reaction. This excess air, which can be 400 percent or more of the exact or stoiciometric requirement, increases the velocity of the gas stream through the solid waste.[1] Air pollution control equipment is heavily taxed because: 1) it must handle a much larger volume of gases; and 2) the gases carry higher particulate loadings because they are blown through the solid waste at a much higher, more turbulent velocity. Increasingly stringent air pollution standards

have greatly increased the cost of air pollution control systems. As a result, incineration of solid waste has generally become economically prohibitive.[2]

Pyrolysis, unlike incineration, is an endothermic reaction. Heat must be applied to the solid waste in order to distill off volatile compounds. During pyrolysis, heat causes carbon (C) to react with water (H_2O) and carbon dioxide (CO_2) to produce carbon monoxide (CO):

$$(2)\quad C + H_2O + \text{heat} \rightarrow H_2 + CO$$

$$(3)\quad C + CO_2 + \text{heat} \rightarrow 2CO$$

This typifies what happens in the pyrolysis reaction. In actuality, cellulose breaks down into new organic compounds which have simpler molecular structures than the cellulose. Although it is not possible to write a typical equation for this reaction, the predominant products are hydrogen, carbon monoxide, methane, carbon dioxide, and various hydrocarbons. Factors such as time, temperature, pressure and the presence of catalysts determine what products are formed.

Because heat is needed to complete the pyrolysis reaction there is some logic in combining pyrolysis zones and combustion zones within the same system. In this way, heat liberated by combustion of a portion of the organic material can be used to drive the pyrolysis reaction, thereby eliminating the need to supply an external energy source.. Carbon dioxide formed in the combustion zone is partially converted back to carbon monoxide in the pyrolysis zone (see equation 3). Many systems currently under development follow this approach.

Monsanto "Landgard" System

Of the systems currently under development, the "Landgard" system developed by Monsanto is the furthest advanced. This is not suprising, however, because it is the simplest of the systems, making no effort to separate the pyrolysis and combustion reactions. Refuse is burned in a rotary kiln with 40 percent of the stoichiometric air requirement.[3] Additional heat is provided by an oil burner to complete the pyrolysis reaction. It could be said that this is a starved air incinerator, rather than a pyrolysis system; nonetheless, a combustible gas resulting from the distillation of the organci material is produced.

The development of this system was begun by Monsanto in 1969 with the testing of 0.3 ton per day pilot plant in Dayton, Ohio.[4] Shortly thereafter, a 35 ton per day prototype plant was put into operation in St. Louis County, Missouri. Data from this unit was used by Monsanto to design the 1,000 ton per day (TPD) facility which is currently under construction in Baltimore, Maryland.

Construction on the Baltimore plant, which is being supported by a $6 million grant from the U.S. Environmental Protection Agency, began in June, 1973 and is scheduled for completion in August, 1974.

One reason why this facility will be constructed so quickly is that it is being purchased by Baltimore under a "turn-key" contract.[5] Monsanto is responsible for the complete design, construction and shakedown of the plant. The contract calls for Monsanto to turn over to Baltimore a complete, operational facility. Additionally, the contract provides for

up to 4 million dollars in performance penalties if the plant fails to meet any of the following standards:

- all existing federal, state and local air pollution regulations
- plant capacity will average a minimum of 85 percent of design capacity for an identified 60 day period
- putrescible content of residue will be less than 0.2 percent

The plant is being built on a five acre industrial site about one mile south of the central business district. A schematic diagram of the plant is shown in figure 1. Incoming mixed municipal solid waste will be shredded to a four inch particle size in one of two 50 ton per hour shredders. Shredded waste will be stored in a live bottom bin having a capacity of 2,000 tons. This will allow the receiving and shredding operation to be fairly independent of minor downstream process interruptions, and will allow the pyrolysis kiln to operate 24 hours a day, 7 days a week. Twin rams will feed the single pyrolysis vessel - a refractory lined horizontal rotary kiln with a nominal capacity of 46 tons per hour. The kiln, 18 feet in diameter and 100 feet long, rotates at 2 revolutions per minute.

Heat required to accomplish the pyrolysis is provided by burning a portion of the solid waste using 40 percent of the theoretically required air. Number 2 heating oil, at the rate of 7.9 gal/ton of solid waste, is also burned in the kiln. Off-gases flow in the kiln counter-current to the flow of solid waste, and exit the kiln at about 1,200^{0} F.

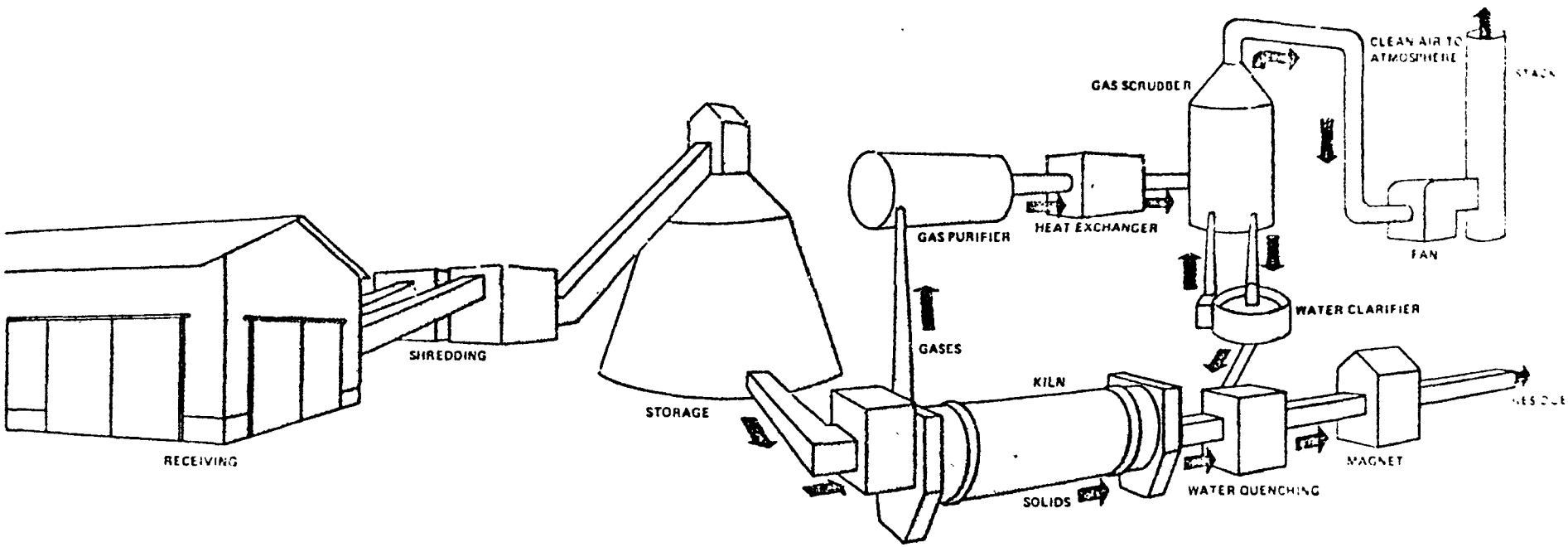

Figure 1. The Monsanto system recovers steam following the pyrolysis of municipal solid waste.

When the combustion/pyrolysis gases reach the system's afterburner (gas purifier), additional air is introduced allowing these gases, which have a heat content of 75-100 British thermal units per standard cubic foot (BTU/scf), to burn to completion. Modular waste heat boilers (heat exchangers) are used to recover 200,000 pounds of steam per hour (lbs/hr). Wet scrubbers, a mist eliminator and a reheater treat the exhaust gas. Recovered steam will be sold under a 5 year contract to the Baltimore Gas and Electric Company for utility distribution. The contract price is a function of the price of No. 6 heating oil. At the time the contract was signed heating oil cost the utility $3.70 per barrel, and the steam price was set at $0.81 per 1,000 pounds. Current oil prices will cause the price of the steam to rise substantially. The full 200,000 pounds will be accepted by the utility 10 months of the year but only 100,000 lbs/hr will be accepted during July and August.

In addition to steam recovery, ferrous metals (70 TPD) and glassy aggregate (170 TPD) will be recovered from the residue. The city anticipates using the aggregate in bituminous paving mixes. The total cost of the Baltimore plant will be $15,852,000. This includes the $14,742,000 turn-key contract price plus land, offsite development and project administration during construction. Total annual operating and maintenance costs based on the 1972 contract price and estimates made at that time were as follows:

Amortization (15 years @ 5%)	$1,525,000
Fuel	276,000

Electricity	329,000
Water	95,000
Manpower	315,000
Maintenance	570,000
Char Disposal	57,000
Total O & M Costs	$3,167,000

Plant revenues were estimated to be:

Steam (1.365 billion lbs at $0.81 per 1,000 lbs)	$1,105,000
Ferrous Metal (21,700 tons at $6.31 per ton)	137,000
Glassy Aggregate (52,700 tons at $2.00 per ton)	105,000
Total Revenues	$1,347,000

Net Operating Costs would thus be:

Total O & M	$3,167,000
Revenues	-1,347,000
Net Operating Costs	$1,820,000

Plant throughput, based on 85 percent availability, will be 310,000 tons per year. This resulted in an estimated net cost of $5.87 per ton of throughput.

Project Engineers are now estimating substantially higher revenues for both the steam and ferrous metals. Although operating costs are also expected to rise, the net operating cost per ton is expected to drop substantially.

Gas Production

The Linde Division of the Union Carbide Corporation has developed a high temperature pyrolysis reactor which produces a fuel gas that can be recovered for off-site use.[6] Original pilot plant work was done in Tarrytown, New York, on a 10-foot-tall packed-column retort having a capacity of 5 tons per day. Union Carbide is currently building a 200 ton per day test facility at South Charleston, West Virginia. This facility is scheduled to go into operation in 1974 for the purpose of confirming engineering scale-up criteria, obtaining operating data and experience on mixed municipal solid waste, and confirming projected economics.

Figure 2 depicts the flow diagram of the Union Carbide process. The key element to the process, called the "Purox" system, is a vertical shaft furnace. Solid waste is fed into the top of the furnace through an interlocking feeder. Oxygen, at the rate of 0.2 ton per ton of solid waste is blown into the base of the solid waste column, where it reacts with char, the solid residue remaining after the pyrolysis of the solid waste. The resultant combustion is at a high enough temperature to melt or slag any noncombustible materials in the residue. This molten metal and glass drains continuously into a water quench tank where it forms a hard, granular material.

The hot gases formed by reaction of the oxygen and char rise up through the descending solid waste providing the heat needed to pyrolyze the solid waste. No external fuel supply is needed to drive the pyrolysis

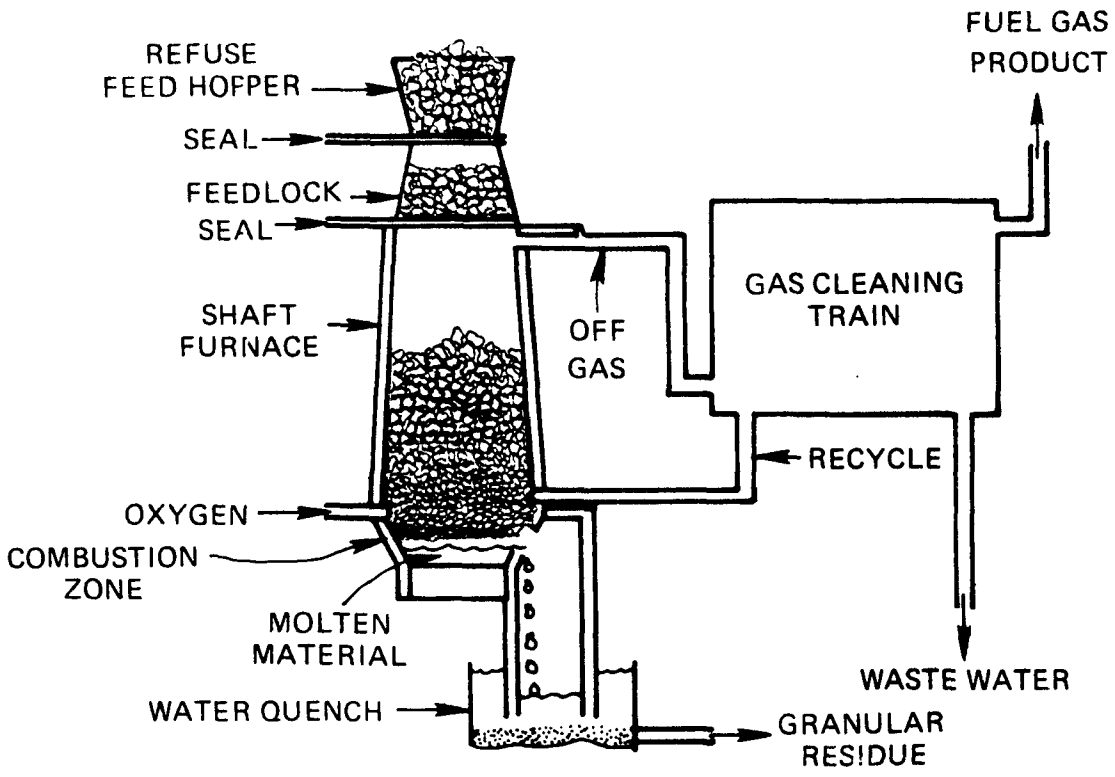

Figure 2. The key element of the Union Carbide process is a vertical shaft furnace.

reaction. In the upper portion of the furnace the gas is cooled further as it dries the incoming solid waste. This lowers the temperature of the gas exhausting from the furnace to about 200^{0} F. The exhaust gas contains considerable water vapor, some oil mist and minor amounts of undesirable constituents. These components are removed in a gas cleaning train consisting of an electrostatic precipitator, an acid absortion column and a condenser.

The gas resulting from the pyrolysis reaction is a clean burning fuel comparable to natural gas in combustion characteristics, but with a heating value of about 300 BTU/cubic foot. It is essentially free of sulfur compounds and nitrogen oxides. This fuel burns at approximately the same termperature as natural gas. The volume of combustion air needed per million BTU's is about 80 percent of that needed for natural gas. The volume of combustion products is about 90 percent of natural gas. Because these characteristics are so close to natural gas, it should be possible to substitute this gas for natural gas in an existing facility. The only plant modification would entail enlarging the burner nozzle because a larger volume of gas must be introduced into the furnace in order to obtain the same heat input.

The limitation on use of this gas is the extra cost of compressing it for storage and shipment. Energy consumption per million BTU's to compress it will be 3.1 times greater than for natural gas. As a result, Union Carbide engineers feel that markets for this gas should be no more than 1 or 2 miles from the producing facility and that only short term storage should be contemplated.

The reason that the "Purox" gas can be recovered for off-site use is that by using oxygen instead of air, the combustible gas product is not diluted by the 79 percent inert nitrogen present in air. To do this requires the use of an oxygen supply which can be relatively costly for small scale plants.

Economics for a full scale Purox system are speculative at this stage of development. However, based on currently available information, Union Carbide has projected the net cost of disposal for this process to be about $4.50 per ton for a 1,000 ton per day plant. The basis for this is a capital cost of $14 million, exclusive of land or site specific design costs. The plant would have three 350 ton per day modules served by one oxygen plant. Amortization and operating costs would amount to about $3 million per year. Revenues from the sale of gas at 75 cents per million BTU's (and a gas yield of 7 million BTU's per ton of solid waste) would be about $1.6 million. Plant throughput on the basis of 85 percent availability would be 310,000 tons per year.

Oil Pyrolysis

The Garrett Research and Development Company has the only "true" solid waste pyrolysis system to reach full scale development. This system, referred to as "flash pyrolysis," produces an oil-like-liquid which can be used as a substitute for No. 6 fuel oil.[7] The concept was originally tested in a small laboratory unit. Subsequently, a four ton per day pilot plant was built on Garrett's property in LaVerne, California. Successful pilot plant performance has led San Diego County, California

to build a 200 ton per day demonstration plant with financial support from the Environmental Protection Agency. Construction is scheduled to begin in December, 1974.

In order for this flash pyrolysis process to work efficiently, most non-organic material must be removed and the organic material must be reduced to small, dry particles. The process is schematically depicted in Figure 3. Incoming municipal solid waste will first be shredded to a particle size of 2 inches or less. An air classifier will then separate the light, organic fraction from the heavy, inorganic fraction. The "lights" will then be dried to a moisture content of 3 percent. A screen will be used to remove additional inorganics and the remaining material will be shredded again to a particle size of -14 mesh.* Ferrous metals are magnetically reclaimed from the classifier rejects and a sand-sized, mixed-color, glass cullet of +99.7 percent purity is recovered from the remaining inorganics by selective crushing and screening, followed by froth flotation.

The pyrolysis reaction takes place in a transport reactor 30 feet tall, and 8 inches in diameter. The fine shredded material is carried into the base of the reactor where it is mixed with burning char. Both materials are carried into the system by spent combustion gases from an auxiliary char burner. In the reactor, the hot, glowing char and solid waste are rapidly mixed as the suspension passes upward under turbulent flow conditions. Reactor temperature is maintained, without any auxiliary

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* The material must pass through a screen having 14 openings per inch.

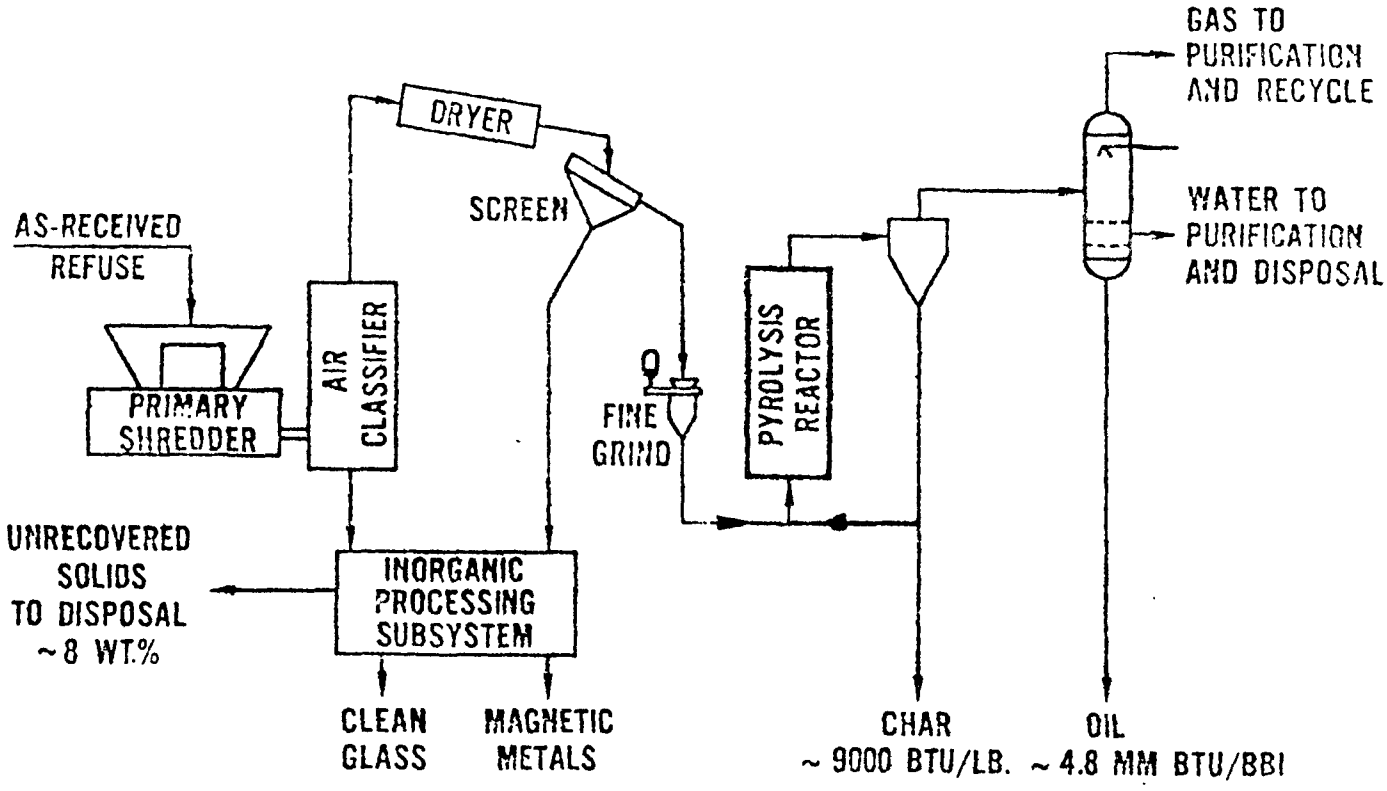

Figure 3. The "Garrett" process produces an oil-like liquid fuel from solid waste.

fuel, at about 900° F. Because the pyrolysis reaction is so rapid, the gaseous products formed are not exposed to the high temperatures long enough for them to thermally degrade. The result is, that when the gases are cooled down to ambient temperatures the compounds formed are organic liquids rather than gases.

After removal of char by cyclones, the hot gases pass to a standard oil recovery collection train. Hot char is either recirculated to the pyrolysis reactor after being reheated in the char heater, or is quenched for disposal.

The hot, char-free gaseous products leaving the reactor cyclone will be rapidly cooled from about 900° F by a venturi quench system using recirculated product oil. In this way, the valuable liquid products, at the rate of about 1 barrel (42 gallons) per ton of solid waste, are recovered before thermal cracking can occur. The outlet gas is further cooled to about 110° F in a packed bed scrubber before being returned to the process. Condensed water from the decomposition of cellulosic compounds amounts to about 13 percent of the pyrolysis feed. This water is cooled in a separate heat exchanger, and a portion is then returned to the scrubber for cooling purposes.

The liquid fuel obtained from the pyrolysis of municipal refuse differs in many important aspects from fuel oil derived from petroleum. It is a complex, highly oxygenated organic fluid, the properties of which are compared with those of a typical No. 6 fuel oil in Table 1. At 0.1 to 0.3 percent by weight, the sulfur content is a good deal lower than even

TABLE 1

TYPICAL PROPERTIES OF NO. 6 FUEL OIL AND PYROLYTIC OIL*

	No. 6	Pyrolytic Oil
Carbon (percent by weight)	85.7	57.5
Hydrogen (percent by weight)	10.5	7.6
Sulfur (percent by weight)	0.5 - 3.5	0.1 - 0.3
Chlorine (percent by weight)	-	0.3
Ash (percent by weight)	0.5	0.2 - 0.4
Nitrogen (percent by weight)	2.0	0.9
Oxygen (percent by weight)		33.4
Heating Value (BTU/pound)	18,200	10,500
Specific Gravity	0.98	1.30
Density (lb/gallon)	8.18	10.85
Volumetric Heating Value (BTU/gallon)	148,840	113,910
Pour Point (°F)	65 - 85	90
Flash Point (°F)	150	133
Pumping Temperature (°F)	115	160
Atomization Temperature (°F)	220	240
Viscosity (SSU@190°F)	90 - 250	1,000

*Source: Finney, C.S., and D. Garrett. The flash pyrolysis of solid waste. Presented at Annual Meeting, American Institute of Chemical Engineering, Philadelphia, November 11, 1973, p. 186.

the best residual oils. However, nearly twice the weight of this oil is needed to obtain an equivalent amount of energy as number 6 fuel oil.

Because it is lower in both carbon and hydrogen, and contains much more oxygen, the average heating value is about 10,500 BTU per pound compared with 18,200 BTU per pound for a typical No. 6. However, fuel oils are generally sold on a volume basis, and since the specific gravities of pyrolytic oil and No. 6 are 1.30 and 0.98 respectively, a comparison of heating values is much more favorable to the former when expressed on a volumetric basis. As Table 1 shows, a gallon (or barrel) of oil derived from the pyrolysis of municipal waste contains about 76 percent of the heat energy available from No. 6.

Pyrolytic oil is more viscous than a typical residual. However, its viscosity falls off more rapidly with temperature than does that of No. 6 fuel oil. Hence, although it must be stored and pumped at higher temperatures than are needed to handle heavy fuel oil, it can be atomized and burned quite well at 240° F. This is only about 20° F higher than the atomization temperature for electric utility fuel oils.

It was found that pyrolytic oil from municipal waste could be blended with several different No. 6 oils.[8] There was very little mutual solubility of the two components, and over a period of hours the heavier pyrolytic oil would settle out from the mixture. Successful combustion trials were carried out, however, at the Kreisinger Development Laboratory of Combustion Engineering, Inc., in Windsor, Connecticut, with blends containing 50 percent and 25 percent by volume of pyrolytic oil with a No. 6 from

an Alaskan crude. Combustion Engineering's formal report on the work states that: "Pilot-scale laboratory tests indicate that pyrolytic oil or blends of pyrolytic oil with No. 6 fuel oil can be successfully burned in a utility boiler with a properly designed fuels handling and atomization system. Ignition stability with the pyrolytic oil and with the blends was equal to that obtained with No. 6 alone; and stack emissions when burning pyrolytic oil or blends indicated negligible amounts of unburned carbon at excess oxygen levels over two percent."[9]

Two precautions must be taken in the utilization of this new fuel. It tends to be thermally sensitive about 200°F, and if held at such temperatures for extended periods, will undergo changes which adversely affect viscosity. It is also somewhat corrosive to mild steel at 200° F, although no attack upon 304 or 316 stainless coupons could be observed. Blending with No. 6 counteracts both its mildly acidic properties and its tendency to suffer with excessive heating.

As a result of these findings San Diego Gas and Electric Company has contracted to purchase the oil from the county. Based on the utility's current cost of $7.00 per barrel for No. 6 oil, the pyrolysis fuel is anticipated to have a value of $4.33 per barrel, delivered. This lower price accounts for the lower heat value per barrel, the additional handling costs, and transportation. Total annual operating and maintenance costs estimated on the basis of 1974 dollars are as follows:

Amortization (15 years @ 5% of $6,343,200)	611,103
Utilities	50,925

Manpower	228,618
Maintenance	147,000
Misc. Costs	26,775
Total O & M Costs	$1,064,421

Plant revenues are estimated to be:

Oil (62,000 bbl at $4.33)	268,460
Ferrous Metal (4,340 tons at $18.20/ton)	78,488
Glass (3,317 tons at $6.40)	21,228
Total Revenues	$ 368,176

Net Operating Costs will thus be:

Total Costs	1,064,421
Revenues	368,176
Net Operating Cost	$ 696,245

Plant throughput, based on 85 percent availability will be 62,000 tons per year. This results in a net cost of $11.23 per ton.

Other Systems

A number of other systems are currently being evaluated at the pilot plant scale. Several are being marketed as full size plants, but at this time no commercial units are known to have been sold. The other systems are as follows:

- Battelle Northwest - has developed a vertical cylindrical reactor in which a packed column of solid waste is progressively dried, pyrolyzed and finally oxidized by an air/steam mixture.[10] The physical arrangement is quite similar to the Union Carbide reactor but operating temperatures are much lower (1600° F). As a result, reaction times are considerably longer. A pilot plant in Richland, Wash., has been operated at 3 to 5 tons per day.

- DEVCO Management, Inc. - has developed a rotary kiln pyrolysis system which is quite similar to the Monsanto process. A 7 ton per hour pilot plant is currently being tested in Queens, New York.

- Kemp Converter - This is an indirectly heated horizontal pyrolysis chamber. Natural gas is burned in a combustion chamber and its radiant energy is passed through the reactor's walls to indirectly heat the organic matter.

- Lantz Converter - This is a batch-fed, sealed cylindrical unit which is indirectly fired by a gas-fired furnace. Temperatures inside the reactor reach 900^{0} to $1,200^{0}$ F. In this system, as well as the Kemp converter special precautions must be taken to insure that no air leaks into the pyrolysis reactor.

- Pyrotek, Inc. - has also developed an indirectly fired reactor. In this unit refuse is continuously fed through the reactor on a moving grate. Heat from a separate combustion chamber adjacent to the reactor drives the process. Although the present pilot plant in Santa Ana, California is electrically heated, the developers of this system expect to use gas produced by the process as the fuel source.

- Torrax - The Torrax system, is very similar to the Union Carbide process. The major difference is the use of air preheated to 2000^{0} F, instead of oxygen to achieve the higher combustion temperatures in the slagging zone. This preheated air is provided by burning natural gas in a silica-carbide-tube air-to-air heat exchanger. A 75 ton per day pilot plant has been evaluated in Erie County, New York.

- University of West Virginia - Dr. Richard Bailie has done extensive research work on the development of fluidized bed incinerators. As an outgrowth of this he has developed a concept for a two bed pyrolysis system.[11] In one bed normal combustion takes place. Hot sand from this bed is then transferred to the second bed where it's heat is used to pyrolyze incoming refuse. After the sand has given up its heat it is returned to the first bed to be heated again.

- Urban Research and Development Corp. - has experimented with several pilot plants of the vertical shaft slagging furnace type. Like the Torrax system, this system uses air preheated to 2,200° F to reach slagging temperatures. Pilot plant testing has been going on intermittently in East Grandby, Conn. since 1968.

Conclusion

The need for better solid waste disposal systems and the need for new sources of energy has stimulated a great deal of interest in the application of pyrolysis to solid waste. Several systems show a great deal of promise. Hopefully, by 1980 municipalities will be implementing similar systems on a wide scale.

The ultimate objective in developing pyrolysis should be to produce a storable, transportable fuel that can be utilized as a fossil fuel substitute without special handling facilities. Then municipalities will be able to readily market the end products of their system and will not have to adapt the location or design of their system to a specific market.

The Union Carbide system and the Garrett system, which were described in this paper, offer the most promise of reaching this objective. The gas produced in the Union Carbide system can be used in conventional furnaces with only the slightest modification. Additionally, short term storage and limited transportation is feasible. The Garrett system's liquid fuel can be easily transported but can only be stored for limited periods of time (about 2 weeks). Special facilities and procedures are necessary when using this fuel, primarily because of it's corresive properties.

Although the Monsanto system does not produce a fuel, it's energy recovery potential is significant, if it can be located near a customer for the steam. Also, the fact that a full size 1,000 ton per day plant will soon be in operation makes it the furthest developed of the pyrolysis alternatives.

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XI

PRESENT CONDITION of SOLID WASTES MANAGEMENT

by

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PRESENT CONDITION OF SOLID WASTES MANAGEMENT

1. Introduction

Hitherto in Japan, flourishing production activity and large-scale consumption have occurred within a small national territory; and as a consequence, there have been growing and diversified waste discharges from places of production, circulation of money, and consumption. Hence, in large cities, and in particular, beginning with Tokyo, waste management reached a serious state of affairs, which was called "the refuse war."

In order to cope with this new kind of situation in society, on the one hand, the old "Public Cleansing Law" was completely revised in 1970, and the new "Waste Disposal and Public Cleansing Law" has been enforced since September, 1970.

2. The Disposal of Refuse

In the area of refuse disposal, the total volume of refuse discharged has increased annually, so that by the end of 1972, the total discharge volume had reached about 92,000 tons daily; that is, each Japanese discharged about 973 grams daily.

Since it was planned to dispose of this refuse by incineration, and also to detoxify, stabilize, and reduce its quantity, there were existing plans for completing facilities with the basic aim of incineration and landfill with the remaining ashes. However, in 1972 the rate of disposal by incineration was about 56%, that of landfill, 41%, and that of composting and other methods, 3%.

For the purposes of waste management, it is planned to complete facilities to incinerate 90% of all combustibles (which make up 83% of all refuse discharged) in the average 1200 grams per person volume to be collected daily by the end of 1975. Besides these incineration facilities, facilities for large refuse, (pulverizers and compressing machines) are planned.

3. Problems to be Confronted in the Disposal of Refuse

(1). Increasing Volume of Refuse

Due to the rise in standard of living since 1960, and the accompanying changes in life styles, etc., the volume of refuse collected by municipalities has grown annually at an average rate of about 11%. Moreover, it is

thought that the decline of resources reclamation collection systems due to the decline of private waste collection services, etc., also contributes to the increasing volume of refuse.

(2). Change in the Nature of Refuse

The level of plastic mixed in with our nation's refuse is abnormally high, and there are cities where it reaches 10% (wetbase, water content about 50%; 1972). It is thought that a cause of the high level of plastic mixed in the refuse in Japan is due to such phenomena as its optimal use in self-service sales packaging products.

Consequently, this, combined with a rise in the level of combustible materials such as paper, also bring about such problems as the increasing volume of heat generated by refuse, a lowering of incineration capacity in incinerators, damage to furnaces by hydrogen chloride gas, worsening in gas discharge and drainage, and problems in base stability in landfill disposal.

As countermeasures, in some cities measures are planned to make refuse incineration facilities highly efficient and to decrease the amount of plastic mixed in refuse by collecting it separately, and so forth. In this case, it remains a question as to how the separately collected plastic should be disposed of. But, through the efforts of the present government and private industry, the development of technology for incineration of plastic and plastic reclamation (plastic ⟶ plastic, heat, oil, etc.) is progressing. Moreover, the development of technology for apparatus for the automatic separation of paper, plastic, and metal wastes, technology for the installation of such apparatus, and for systems for the dry distillation, pyroxis, and reuse as gas or oil for refuse is progressing within a national project, and a pilot plant is being built.

A matter which has become a problem associated with the diversification of refuse materials is that of large refuse, which is composed primarily

of household electrical appliances. Since these are large and moreover incombustible, they have come to be dealt with by the completion of facilities for pulverization and compression; but the necessity of more landfill due to the pressure of increased volume, and the necessity of predisposal of wastes containing materials which could contaminate the environment, such as PCBs, have become a burden to disposal systems in municipalities.

(3). Collection and Transportation of Refuse

In Japan, collection and transportation take place simultaneously; since transportation takes place without processing, and in small vehicles suited to collection operations, the efficiency of transport lowers along with the worsening of the traffic situation. Moreover, due to the increase in number of vehicles which accompanies increasing refuse volume, the convergence of large traffic volumes of refuse collection vehicles in the vicinity of incineration facilities and landfills [illegible]

the source of the Tokyo refuse war.

In order to solve these problems, reshipping and conversion to large-volume transport by means of the establishment of relay bases is beginning, and the possibility of the adoption of refuse transport pipes is also being studied.

(4). Facilities in the Environs of Refuse Incineration Plants

When refuse incineration facilities are built, opposition from prior residents of the area is strong, and there is trouble in maintaining sites. Therefore, along with the improvement of refuse incineration facilities, steps towards restoration vis a vis area residents, such as forestation in the environs of the facilities, the creation of parks, the establishment of warm water pools thrcugh use of waste heat, and public presentations are generally being taken.

XII

Collection and Transport of Household Solid Wastes

1974. 9. 24

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Collection and Transport of Household Solid Wastes

1. The Present State of Collection and Transport

In 1971, Governor of Tokyo Metropolis declared his attitude to be tackled with the difficult problem of waste management by using the term "war against wastes". In the past three years since then various improvements were made in various fields of waste management, but no basic solution has yet been made of this problem. The greatest reason for this may be that the change in our country's circumstances of waste (household solid wastes) were so rapid in the past twenty some years that the administrative measures for waste management have been unable to catch up with the changes.

The economy of our country continued to grow at a high rate from the first half of the 1950's. During this period the population came to be concentrated in cities, the society was converted to that of mass consumption and the undertakings dealing with used articles, repair works and collection of waste articles have declined. All this has caused the generation of solid wastes to increase quite drastically in quantity. And together with the rapid increase of waste, there has been a change in the quality of waste due to the rise of people's living standard and the spread of the use of synthetic chemical products. As a result, the management of solid wastes has become very difficult to be handled by the existing systems. Furthermore, with the increased congestion of road traffic, the strengthening of traffic regulations and the trend to place intense processing and final disposal plants at a great distance from the built-up areas, changes have been brought about in the state of waste collection and transport as well as in that of the people's attitude toward their environment, which confront the administrative actions for waste management with difficulties.

The administration of waste management in Japan is based on "Wastes Disposal and Public Cleansing Law" and is mainly taken charge of by the Ministry of Health and Welfare.

As for the present way of waste collection and transport in our country, at a fixed time of a fixed day (once every other day to every four days) each individual household brings polyethylene containers, vinyl bags or paper bags containing refuse onto a certain place on a road or a refuse dumping ground adjacent to a road, and these bags are collected by a small-size waste collection vehicle (dump truck or packer car).

As to the present state of waste management, a survey conducted in 1972 showed that about 87.8% of the country's total population, that is 87.8% of 106.2 million persons, availed themselves of the household solid waste collection service delivered by each municipality. The total of the solid waste collected throughout the country amounts to 92,000 metric tons per day, which is to be collected and transported by about 22,900 vehicles. Since the roads in Japanese urban areas are usually rather narrow, smaller cars are adopted as waste collection and transport vehicle, and their average loading capacity is 2.0 metric tons (see Table-1).

As is shown in Table-1, both the number and the loading capacity of collection and transport vehicles are rapidly increasing, and especially noted is their increase after 1971. As for the types of vehicles, there has been a remarkable increase in the number of special vehicles with [illegible] designed devices for refuse collection and transport only. As is shown in Table-2, the average solid waste collection volume of a collection vehicle per day and that of a collection worker per capita have been on the increase by 6%/year before 1970 and on a sudden decrease after 1971, which shows aggravation in the circumstances of collection such as

traffic conditions. As to the expenditure of solid waste management, on the other hand, it has been rapidly uprising throughout the country as is illustrated in Table-3. The average increase rate of the expenditure has been 125%/year in the past eight years, but it has been remarkably drastic after 1971. It is considered that most of this increase in expenditure is due to the hike of cost of collection and transport.

2. Problems of Waste Collection and Transport

There are various problems to be listed concerning solid waste management, which have all come to the fore in our country. But in relation to the waste collection and transport, they can be grasped from the four aspects, public cleansing administration, daily life of the people, urban environment and development of new towns. For the administration of public cleansing, the problems to be coped with are the increased probability of the danger to be caused to the waste collection workers the difficulties of site selection of waste disposal center (incinerating factory, plant for reprocessing waste into fertilizer, etc.) and waste dumping ground (reclamation ground, etc.) due to the oppositions and resistance raised by residents in the area against the concentration of waste truck traffic, the drastic uprise of the waste collection and transport cost (from collection to disposal).

While on the part of the people's daily life, the major problems are the accumulation of rotten refuse left out for a long time because of the decrease of refuse collection frequency, the waste becoming more massive and bulky the people's having to be time-bound to put out the waste at a fixed time, etc.

In the viewpoint of the urban environment, the sidewalks of roads or

sometimes even the road sides in urban areas have the household solid wastes accumulated on them, which can be an impediment to the traffic of pedestrians or bicycles. The waste collection cars have to go slow along the roads and have to stop a while frequently in order to collect the accumulated wastes, which is one of the factors deteriorating the road traffic efficiency.

Moreover, in the vicinity of waste incineration plants or waste dumping ground, there is the traffic of waste transport vehicles in concentration occupying a major portion of the traffic volume. This gives rise to traffic accidents, noise, vibration, exhaust gas and other unsanitary conditions, which all cause much nuisance to the nearby residents. These are the major problems to be dealt with from the standpoint of road administration or protection of urban environment, and they seek immediate solutions.

One of the characteristic features of our country is found in the construction of large-scale new towns in the outskirts of big cities. The municipality with big vacant land in which such new towns are to be developed usually has a small population and limited industries and as a matter of course it cannot at once be adapted to the scale of the new town in terms of financial scale as well as administrative competence.

Accordingly, when the municipality has all of a sudden accommodated the population as many as several times of its original within the same municipal boundary, this measure will be imposed on every aspect of the administration and the finance of the municipality. With respect to the collection and treatment of solid wastes, for example, the municipality must increase the number of workers to a sufficient extent within a very short time. Such an increase of the municipality's burden both administrative and financial is not limited to the administration of public

cleansing, but it has emerged in the administration of education and many other fields. This is often the reason why the development of a large scale new town tends to be rejected by municipalities. This is one of the most difficult problems for our country.

3. Measures for Collection and Transport

A number of measures have already been executed for the solution of above-mentioned problems.

As to the containers of wastes for collection, they used to be waste boxes made of wood. But nowadays polyethylene garbage containers are being adopted, which have unified sizes and forms easy to be collected and much more sanitary as well as good in appearance. More spreading in use than polyethylene containers now are vinyl bags and paper bags with improved convenience in collection and sanitation. Storage containers (public containers specially designed for mechanical collection and/or transport) are also partially used.

As for the waste collection places, collection at waste dumping ground is now adopted instead of the former collection at each household in order to improve the efficiency of collection. In some regions it is obligatory for large buildings to provide an access for waste collection vehicles.

Regarding the collection time, it is now fixed hour fixed day collection instead of collection at irregular frequency.

The waste collection vehicles used to be dump trucks, but now they are changed to special vehicles such as packer cars with improved sanitation and efficiency. The use of container cars is also being enhanced in some regions.

The transport of collected wastes is closely related to the road traffic condition in our country. Conversion is now being promoted from the direct delivery by small collection vehicles to the transport by large transport vehicles, large container cars and transport vessels. However since the land acquisition of transit base for transshipment from collection vehicles to transport vehicles is very difficult, the rationalization of transport system is making a very slow progress at present.

Apart from the above measures which have so far been taken for the rationalization of refuse collection and transport system, new measures are about to be established mainly from the standpoints of city planning and road administration.

The cities have to meet various requirements such as that they have to be preserve sanitation and beauty, that the impediments caused to traffic by refuse collection have to be eliminated, that the refuse collection system has to be convenient for the residents, that the labor of refuse collection and transport must be saved, etc. In order to satisfy these requirements, special facilities such as pipes for the exclusive use of household solid waste management have to be provided to cities just as sewage systems as their own facilities for the management of liquid wastes. In this context, it is proposed that such facilities for the management of household solid wastes should be constructed within the total framework of urban facility construction.

/ Automatic Collection and Transport System

/ vacuum transport system has been developed recently as one of the new systems of solid waste collection, and it is more often applied than ever in various new towns of European countries. Also development is now

under way for a system to transport all the collected solid wastes by pipes over a long distance or for a driverless guide way system. And, a study is being made as to a concept of formulating a future automatic collection and transport system by combining these new types of hardware. This concept of refuse collection and transport system is as follows:

A refuse throw-in box (refuse post) is set up at every household or at one place for every 20 - 30 households in which they can throw solid wastes other than big refuse. And through the vacuum collection pipes which are distributed throughout a city, the wastes are sucked in and carried to a waste collection center by valve operation controlled by a central control system. As the economical waste suction distance of this system is estimated at 1.5 - 2.0 Kms, a small-scale new town will be able to adopt a complete household solid wastes management system by connecting this system directly with an incineration plant. However, in the case of an area where the incineration plant is located far from the collection center or a large-scale new town and a built-up area covering a wide area, wastes have to be re-collected and transported over a long or a medium distance, which will require a further improved system. As the system of long or medium distance transport of this kind, capsule transport, pressure pipe transport and vacuum transport are being developed. Moreover, in case of big cities, where a long distance and mass transport is required, container transport of solid wastes by a new traffic system (such as medium-volume guide way system) will be more advantageous in most cases than the above-mentioned capsule transport and others.

In this way, household solid wastes can be automatically collected and transported in areas from a small-scale new town to big cities by the combination of vacuum collection, capsule transport and medium-volume guide way systems.

It is considered that the pipes for the automatic collection and transport of household solid wastes are to be placed mainly under roads. Especially, with respect to refuse posts which are to be provided to residential areas with lower buildings, they cannot function to serve the residents unless they are placed on sidewalks or on the land abutting on roads.

On the other hand, however, the road area has already been applied to complicated uses with various attachments and properties built on or below them. The result is that the excavation for the maintenance and repair of roads causes much hindrance to road traffic at present.

In order to prevent that hindrance, the Road Law (Law No.180, 1952) provides that any exclusive use of road shall be determined by the judgements of the road authority except when there are particular provisions of the law. Pipes and cables under roads must be well adjusted and coordinated and located according to a definite plan. For this purpose, the construction of common ducts for utility pipes and cables is being promoted in order to accommodate these in a highly intensive and efficient way. Simultaneously, a policy is being adopted in road administration to approve the placement of only those as are designated by city planning as supply and disposal facilities.

Therefore, it is very important to include refuse incineration plants as well as the pipes for refuse collection and transport as an indispensible part of city planning, not only because they can be planned and constructed in harmony with the land use plan of the neighboring area and other city facilities but also because it enables a better road administration.

5. The Present State of Automatic Collection and Transport System in Japan

At the time when the national budget of fiscal 1974 was under deliberation, a proposition was raised that the national government should subsidize the construction cost of the automatic collection and transport system to be undertaken by local governments. This proposition was rejected as being premature. However, there is an increasing demand for the establishment of the automatic collection and transport system in new towns, and this subsidy system is strongly demanded again at present in the compilation of 1975 national budget.

Table-4 shows the areas for which the construction of the automatic collection and transport system is already decided. In other various large-scale new towns and redeveloped areas studies are now going on as to whether the same system should be established.

As for the development of hardware for the system in our country, there are at present 7 industrial groups for vacuum collection system, 3 industrial groups for capsule transport system (a system to transport capsules by the movement of liquid in pipes), 1 group for pressure transport and 9 industrial groups for PneT-type system, which are engaged in research and development.

Five of the seven industrial groups working on vacuum collection system have technical tie-up with foreign companies, and the other two are domestic companies with no tie-up with foreign countries. Three of these seven companies installed full-sized test plants in 1972 and afterwards, and they are conducting various experiments for the understanding and the solution of the problems of refuse collection in our country.

Concerning the capsule transport, one of the three industrial groups installed a full-sized test plant in 1972 and has executed various experiments.

As to pressure transport system, though only one group is engaged in this system, the group has installed a test plant of full size and has succeeded in transport experiments with its own domestic technology.

With respect to PRT system, the construction plan is being promoted mainly for passengers. There are some groups which are proceeding with the development of hardware of this system for refuse transport, though there is yet no specific plan to construct the facilities exclusively for refuse transport immediately right now. The development of PRT system in our country is now undertaken by five industrial groups of domestic technology and other four industrial groups which are under technical tie-up with foreign countries. Test lines have been provided at seven places where various experiments are being conducted. For the construction of PRT system, demands have been raised from three new towns in the compilation of 1975 national budget for a government subsidy to be extended as a part of road construction expenditure.

6. Conclusion

As mentioned above, so far as the hardware of the automatic waste collection and transport system is concerned, it is the manufacturing groups that have been engaged in research and development in our country. In order to establish this system as one of the urban public facilities, several problems have to be solved. In the first place, the standards for the system must be set up such as the standard of planning, the standard of structure, the standard of safety and security, the standard of environment, etc., which are under study at present.

The second problem arises from the fear that the users of this system might discharge whatever they consider are wastes, because it is too

convenient, and as a result the amount of wastes might be the more expanded. This problem will be solved by strengthening the collection of wastes by sorting them by kind that has recently been put into practice in most cities of Japan as well as by further promoting the development of waste sorting techniques which are now under development along with the propagation of this system.

The third problem is that measures have to be taken in order to prevent this system's being used as a place in which to conceal the evidences of crimes. Various studies are being made for this problem, but so far no conclusive solution has been worked out.

The fourth problem is about the establishment of the principle for the allocation of construction expenses and maintenance or management expenses of the system. As for the construction expenses, a direction has been fixed to subsidize local governments. However, regarding the maintenance and management expenses, there is an urgent necessity to establish a principle for a fair allocation of the expenses since the ordinary waste collection of household solid wastes is providing free service for residents.

The development of science and technology is amazing indeed in recent years. However, since the development of science and technology is too rapid and the society has not been sufficiently prepared to accept the development, there are many cases that they cannot be presented to the use of the people. The utilization of the latest technology should be commenced only after a sufficient assessment is made of the merits as well as the demerits as ill effects of the technology. It is required that efforts should be made in order to continually grasp the up-to-date information of the development of technology which will lead to the welfare of the people as well as to nurture the readiness of the society to accept

the technological development. This should be done not only in the field of automatic waste collection and transport system of our concern but also in other various fields.

Table 1. The number and the loading capacity of waste transport vehicles

	Special transport vehicle		Ordinary truck		Others		Total	
	Number	Loading capacity (metric ton)	Number	Loading capacity (metric ton)	Number	Loading capacity (metric ton)	Number	Loading capacity (metric ton)
1965	4,400	8,600	5,600	11,800	1,200	1,300	10,200	21,700
1966	4,900	9,300	6,300	12,300	900	900	12,100	22,500
1967	6,400	12,100	6,100	12,700	700	700	13,200	25,500
1968	6,900	13,700	6,500	14,000	700	700	14,100	28,400
1969	8,200	13,700	6,700	13,900	500	600	15,400	28,200
1970	9,350	18,000	6,600	13,900	600	800	16,500	32,700
1971	10,210	18,700	8,600	18,600	600	800	19,400	38,100
1972	11,960	23,300	10,000	22,000	900	1,300	22,900	46,700

Table 2. Collection and transport by municipality direct management

	1.Quantity of waste collection (ton/day)	2.Number of collection and transport vehicle	3.Number of workers for waste management (person)	4.Average wages (¥1,000/year)	5.Maintenance cost of vehicle (¥1million)	6.Maintenance cost per vehicle (¥1,000)	7.Quantity of waste collection per worker (metric ton/day)
1965	37,600	8,600	34,600	607	2,300	270	1.1
1966	42,500	9,500	38,200	681	2,800	300	1.1
1967	47,400	9,500	37,100	775	3,000	310	1.3
1968	53,400	10,000	42,700	815	3,315	330	1.3
1969	59,100	10,600	43,000	976	3,700	350	1.4
1970	67,700	11,100	44,300	1,130	4,630	410	1.5
1971	60,300	14,600	48,900	1,411	5,030	340	1.2
1972	66,900	16,512	61,600	1,452	6,470	390	1.1

Table 3. Expenses for solid waste management

	1. Total expenses (¥1 million)	2. Index	3. Amount of solid waste management per year (1,000 tons)	4. Unit cost of waste management (¥1,000/ton)
1965	44,189	100	12,380	3.6
1966	52,450	119	13,810	3.8
1967	65,109	147	16,021	4.1
1968	75,465	171	18,144	4.2
1969	94,333	214	20,699	4.6
1970	120,419	272	23,359	5.2
1971	177,533	402	24,501	7.2
1972	255,013	577	27,574	9.2

Table 4. Areas designated for automatic waste collection and transport system

Name of city	Name of area	Outline of the area: Planned population (person)	No. of planned household	Planned area (ha)	Target year to commence dwelling	Target year to commence service of the system	Executing body	Remarks
Narita-shi	Narita New Town	10,858	-	24.4	1974-78	Apr. 1977	Chiba Prefecture	Collection
Yokohama-shi	Minamitotsuka	-	-	-	-	Apr. 1977	Yokohama City	transport 400 tons/day
Ashiya-shi	Ashiyahama	20,000	6,000	125.5	1977-80	Apr. 1978	Hyogo Prefecture Housing Corporation	collection
Kobe-shi	Port Island	40,000	4,000	103	1975-80	Apr. 1978	Kobe City Housing Corporation Japan Housing Corporation	collection
Osaka-shi	Morinomiya	13,800	3,398	10	1975-78	Oct. 1975	Osaka City Housing Corporation Japan Housing Corporation	collection
Osaka-shi	South Port Town	40,000	9,910	110	1976-78	Mar. 1977	Osaka City Housing Corporation	collection

XIII

ACTUAL CONDITIONS IN REFUSE MANAGEMENT IN JAPANESE CITIES

by

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AUGUST, 1974

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ACTUAL CONDITIONS IN REFUSE MANAGEMENT IN JAPANESE CITIES

1. Content of City Refuse

City refuse is solid waste materials discharged from city residents' daily life. It is classified as garbage, rubbish, or large refuse. In particular, a mixture of garbage and rubbish is called household refuse.

It is the responsibility of the local governments to manage this city refuse, and it is a fundamental principle that local governments will do all of the collection, transport, intermediate treatment, and final disposal. The methods of their treatment processes differ according to such factors as city location, shape, and financial situation.

2. The Nature and Volume of Household Refuse

The volume of household refuse discharged differs by city, season, standard of living, lifestyle, and so forth, and in Japan it averages about 1 kg. per day

per person. This unit discharge volume increases in proportion to city size and in proportion to a resident's income level. By 1985 it is estimated it will increase to about 1.5 kg. per day per person.

The nature of household refuse also differs seasonally, annually, and regionally. As shown in Figure 1, which indicates the nature of household refuse in Yokohama in 1973, Japanese household refuse is distinctively high in water content and low in heating value.

3. Concerning Large Refuse

As housing conditions become more crowded and standard of living rises, when televisions, washing machines, and furniture, which were used as permanently durable goods, break down or go out of style, they begin to be used as non-durable consumer goods, new ones are bought in their place, and, if useless, they are discharged as refuse. These are called large refuse, and, since compared to household refuse, they are larger and more often include incombustible materials, there have been problems in the past as to smooth [illegible] in matters of collection methods and manage-

ment technology. It became necessary to collect them separately from household refuse and to insert pulverizing and compressing processes into the management process.

4. Collection of City Refuse

General methods include mixing garbage and rubbish and storing them in receptacles which are periodically collected by collection vehicles and transported to treatment plants and landfill disposal sites. The method was selected by which it is collected from a prescribed place at a fixed time on a fixed day. In general it is collected with a frequency of two or three times a week.

Large refuse is collected either once a month or once every three months on a fixed day. So that large refuse may be brought to the prescribed freight collection spots in the road on the appointed day and time, it is necessary to have sanitary storage places within the house, while a receptacle of capacity to match the frequency level and volume of discharge, and a place to house this receptacle must be suitably maintained.

In this kind of collection and transportation system, on the average in Japan, the standard worker handles a volume of about 1.5 tons daily, not an unhealthily high work load.

The cost of city refuse management is handled by a tax paid by city residents, yet in the cost of refuse management, the majority (about 70%) is taken up by collection and transport.

Hereafter, it is necessary to have optimum distribution of personnel and collection vehicles, and a uniform standard size and shape for receptacles; also, it is necessary to optimize the number and location of collection points and the scale and distribution of disposal sites, and, along with a plan to make standard transportation more efficient, it is necessary to develop and adapt technology for such things as the improvement of heavy vehicles, train transportation, adaptation of transportation in containers, and compressed air transportation.

5. Treatment of City Refuse

Such methods as incineration, composting, and landfill are used to treat household refuse, and in

the vicinity of cities, where population density is high and the flow of materials is taxing, incineration is emphasized in order to deal with it sanitarily and in a short time.

However, there is a certainty of opposition from residents to the building of incineration facilities, and they have become representative of disliked municipal facilities.

Hereafter, environmental pollution controls for incineration facilities will have to be completed. For example, a standard for soot discharge of below 0.03 g/$STPm^3$, and a ground level concentration of toxic gases such as SO_x, NO_x, and HCl, of below 0.005 ppm. are planned for large cities; these standards are stricter than national standards and are independentely formulated.

Buildings constructed should be of a design which matches municipal environment.

Waste heat should be used reasonably. For example, warm water pools, facilities for the benefit of the elderly, and the improvement of benefits for residents of the areas near refuse treatment plants should be planned.

At present, since the heating value of house-

hold refuse is 1200-1500 kcal./kg., it has a heating capacity about one quarter that of coal or city gas, and can be used for the generation of electrical power, for community hot water supplies, community central heating systems, and so forth.

Large refuse is crushed, the combustible materials incinerated, recyclable materials reclaimed as resources, and other materials used for landfill. Since the technology of crushing and separation is new, future technological developments are anticipated.

Systems for the reclaiming and use of paper, glass, metal, etc., which are contained in household refuse, are being researched, and there are methods both for separation at the time of discharge and for mechanical separation of collected garbage, and the former is working well through residents' organization; but there are problems in that the cost of reclaimed materials is unstable and cooperation by residents is necessary.

Research and development are being carried on concerning methods for compressing garbage and using it for engineering materials, or solidifying the re-

maining ashes after incineration and effectively using them for building or engineering materials.

Composting is one influential disposal method, since it is in effective use, but the demand for compost has declined. Since the era of demand for compost does not conform with manufacturing, it is necessary to have a large volume of stock, and so it does not often occur in Japanese cities.

Outside of incineration, most disposal is done by landfill. Landfill of both incombustible refuse and of ashes left after incineration occur together. Landfill sites have been established in both suburban hills and waterfronts, but since there is the problem of water contamination with waterfront landfill, most cities use mountainside landfill.

Landfill occurs by piling up alternate layers of refuse less than 3 meters thick and of soil cover more than 0.5 meters thick. In order to prevent environmental pollution, and as a countermeasure against foul odors, plenty of covering materials are used, and insecticide is dispersed to prevent proliferation of harmful insects. However, if there is no treatment of

water contaminated by leachate, or if equipment for the ventilation or combustion of gas produced from the refuse layers (50-60% methane) is not built, then complete environmental pollution controls have not been planned.

TREATMENT OF LEACHATE AND GASES DISCHARGED FROM LANDFILL SITES
--Using Yokohama as an Actual Example

by

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AUGUST, 1974

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TREATMENT OF LEACHATE AND GASES DISCHARGED FROM LANDFILL SITES
--Using Yokohama as an Actual Example

1. Volume of Landfill Refuse

In Yokohama, of the approximately 3000 tons of refuse collected by the city daily, about 1500 tons are disposed of by incineration, while the remaining 1500 tons and about 300 tons of incineration ash are disposed of through landfill.

2. General Aspects of Landfill Sites

Landfill sites have been established in the city's suburban mountain valleys, and currently are four in number, covering areas of between 80,000 and 550,000 square meters. Since the landfill sites are small in scale, the period of landfill for one site is about two years.

Landfill sites are land borrowed from private landowners in order to landfill refuse, create land, and return it, but there are two landfill sites which have not yet been returned because the production of leachate and gas has not yet ceased.

3. Landfill Method

Valley ravines are filled with refuse and made into

level land, with two to four layers of refuse and covering material piled on the slopes. One layer of refuse is about two to three meters thick, while one layer of covering material is about half a meter thick. The final layer of covering material is approximately one meter thick.

Since the refuse is decomposed by anaerobic decomposition, leachate and gas are produced.

4. Treatment of Leachate

(1). Volume of Leachate

Water contained in refuse is exuded, as are rainwater and water contained in decomposed organic materials, both of which have permeated the layers of refuse.

Consequently, the water volume differs according to topography, climatic conditions, and the nature of the soil, but it is largely determined by the valley's water volume and precipitation prior to landfill

(2). Method of Leachate Discharge

Prior to landfill, perforated drainage pipes are layed in advance, as indicated in Figure 1.

(3). Quality of Leachate

Leachate will exude from landfill sites after about the first six months. The quality of this water is as follows:

pH	5 - 6
BOD	1000 - 2000 ppm.
SS	500 - 1000 ppm.
Total Fe	150 - 350 ppm.
Total N	100 - 300 ppm.

(4). Changes in Leachate Volume and Quality

Leachate starts six months after landfill begins, and six months after landfill is terminated, the water volume decreases to about one-third, while the BOD concentration also lowers to one third. (Figure 2).

During precipitation, the water volume increases, but since the concentration of BOD does not decrease, the concentration of pollutants decreases.

It takes about two years until the secretion of leachate ceases.

(5): Treatment of Leachate

Since drainage from landfill sites flows into rivers and irrigation canals, it must be purified. Many treatment methods were tried, but the method of combining activated sludge processes and the coagulating sedimentation process was the most successful. A flow chart of this process is shown as Figure 3.

The standard for the quality of treated water is as follows:

BOD	below 30 ppm.
SS	below 70 ppm.
Total Fe	below 3 ppm.

5. Exhausted Gas

Since refuse decomposes anaerobically in landfill, combustible gas is produced. Gas composition is mainly CH_4, CO_2, and N_2. It is necessary to provide gas vents as well as burners, and to ventilate and burn it.

Gas production is large principally in the environs of the landfill. It is thought that this is due to the creation of a fault between the refuse layers and

the base ground layer. The conditions for the construction of gas vents are indicated in Figure 4.

Gas ventilation pipes are 15 cm. perforated vinyl chloride pipes which are layed about three meters below the surface of the final layer. Gas passes through these pipes, flowing from low to high locations.

Ventilation pipes are spaced at approximately thirty-meter intervals in level land and at fifty-meter intervals in sloping land; they draw the produced gas up to the surface of the land to be burned. Since the gas has a pressure of 3-5 mm.Aq., and blows out of the pipes naturally, this natural draft is used in its combustion. An outline of the combustion facilities is given in Figure 5.

Since gas ventilation pipes and combustion facilities are built on the topmost refuse layer, combustion starts from the time that landfill is for the most part over. Gas combustion continues for three years after landfill is terminated and the final soil covering occurs.

Although the volume of gas produced has not been measured, there is a tendency for the volume of gas produced to be [illegible] in continuing clear weather and higher during precipitation.

XIV

TREATMENT OF TOXIC WASTES

by

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TREATMENT OF TOXIC WASTES

1. Introduction

In January, 1973, a conference was held in Tokyo concerning the general administration of waste management in Japan; a report was given at the First Japan-U.S. Conference on Solid Waste Management. In it, an explanation was given covering all phases of the "Waste Management and Public Cleansing Law" (1970, Law Number 137, afterwards referred to as the "Waste Management Act"), which is the focus of the movement to advance waste management. The explanation included the purpose of the law, its definition of waste materials, and explanations of duties of the enterpriser, general waste management, industrial waste management, penal regulations, and so forth. However, standards for waste collection, management, and disposal are prescribed by the Cabinet Orders based on the "Waste Management Act" and on the "Marine Pollution Control Law" (1970, Law Number 136); and since the standards for collection,

transportation, and disposal of the toxic waste materials to be discussed are included in these Cabinet Orders, we will begin our explanation with these standards.

*Radioactive wastes are not dealt with here as if included in "toxic wastes."

2. Standards for the Collection, Transportation, and Disposal of Toxic Wastes

2-1. The Range of Toxic Wastes

Among industrial wastes, those treated as toxic wastes are of four kinds (applicable in the conditions listed below): sludge, slag, acid wastes, and alkaline wastes; related toxic materials are of seven kinds: mercury and mercuric compounds, cadmium and cadmium compounds, lead and lead compounds, organic phosphate compounds, Cr^{+6} compounds, arsenic and arsenic compounds, and cyanide compounds.

Table 1

(1). Sludge produced at institutions or factories having the equipment described in the left-hand column of Table 1, or such products which have been treated for disposal, which include the materials mentioned in the right-hand

column of the table (limited to those which do not conform with the standards set by Order of the Prime Minister's Office).

(2). Authorized public sewerage sludge or such sludge treated for disposal, which include one of the above-mentioned seven kinds of toxic materials (limited to those which do not conform to the standards set by Order of the Prime Minister's Office).

(3). Slag or slag treated for disposal, which include some of six of the above-mentioned toxic materials, but do not include cyanide compounds (limited to those which do not conform to the standards set by Order of the Prime Minister's Office).

(4). Acid or alkaline wastes produced at factories and institutions owning the equipment described in the left-hand column of Table 1, which include materials in the right-hand column of the same table.

(Note:) "Authorized public sewerage sludge," according to the Cabinet Order on Sewerage Act

(1959, Cabinet Order Number 147) Number 13 article 2, is authorized sludge, but as of the present (August 1974), such authorization has not been achieved.

2-2. Standards for the Collection, Transportation, and Disposal of Toxic Wastes

(1). Standards for Landfill Disposal

1). As for sludge, authorized public sewerage sludge, or such materials treated for disposal (materials described in 2-1(1) and (2)), which include mercury and its compounds, or cyanide compounds, and are judged to be toxic:

(1). If these materials are solidified in concrete, landfill occurs so that there is interception of any seepage into groundwater and public water areas.

(2). If these materials are not solidified in concrete, they are to be detoxified and used in general landfill, or

(3). Through solidification in concrete, the toxic materials are treated so

that they will not leak out; if they are non-toxic, general landfill may occur; if they are toxic, landfill must occur in such a way that seepage into groundwater is intercepted.

2). As for sludge, authorized public sewerage sludge, or these materials treated for disposal (materials described in 2-1(1) and (2)), which include cadmium and cadmium compounds, lead and lead compounds, organic phosphate compounds, Cr^{+6} compounds, arsenic and arsenic compounds, and are therefore materials judged to be toxic; and slag or slag treated for disposal, which includes any of six of the toxic materials except cyanide (materials described in 2-1(3)), and are therefore judged to be toxic:

(1). If they are reduced to non-toxic materials, general landfill may occur, or (otherwise)

(2). Seepage interception landfill must

take place.

3). When sludge landfill occurs, the following standards are prescribed, regardless of whether materials are toxic or non-toxic:

(1). In cases where sludge landfill disposal occurs (excluding wet-type landfill), prior incineration using incineration equipment must occur, or the water content must be below 85%.

(2). In cases where organic sludge (sludge removed from public sewers or river basin sewers, excluding materials digested using digestion facilities and those materials whose organic content is smaller than that of materials digested using digestion facilities; same below) is disposed of by wet-type landfill, prior incineration using incineration equipment must take place.

(3). For organic sludge or such sludge

treated for disposal (excluding materials incinerated with an ignition loss of less than 15%, and those solidified in concrete:

(a). In cases of landfill disposal of wastes generally more than 40% organic wastes, each landfill layer should be less than 50 cm. thick.

(b). In general, in cases where it's less than 40%, each layer should generally be less than 3 m. thick

Moreover, each layer should have a surface cover of about 50 cm. of sand and soil. In cases of small scale landfill disposal, however, (landfill in an area of less than 10,000 m^2 or of a volume less than 50,000 m^3), or in cases of landfill disposal utilizing subterranean air spaces, this is not to be applied.

Also, along with the provision of ventilation equipment for the landfill area and the removal of methane and other gases produced in the area, measures necessary to prevent the outbreak of fires should be practiced. But in cases of small scale landfill disposal this is not to be applied.

4). When landfill using industrial wastes occurs, the following standards are applied:

(1). Necessary precautions should be taken to prevent offensive odors from emanating from the landfill site.

(2). Rats should be prevented from living on landfill sites, and mosquitoes, flies, and other harmful insects should be stopped from multiplying there.

(3). Landfill sites should be enclosed with a fence and the fact that they are areas for the disposal of indus-

trial wastes should be indicated. (At toxic industrial waste landfill sites, that they are areas for the disposal of toxic industrial wastes.

(4). Landfill sites should be insulated to protect public river basins and ground water. But in cases of the disposal of non-toxic industrial wastes, when the necessary precautions are taken to prevent contamination of public river basins and groundwater by landfill leachate, this is not to be applied.

(5). Landfill disposal of acid and alkaline wastes (described in 2-1 (4)) is prohibited, regardless of whether they are toxic or non-toxic.

(2). Standards for Marine Disposal

1). Sludge or authorized public sewerage sludge (materials described in 2-1(1) and (2)), slag (materials described in 2-1(3)), or

acid or alkaline wastes (materials described in 2-1(4)), which are judged to be toxic, must not be disposed of in the oceans.

2). Sludge or authorized public sewerage sludge (materials described in 2-1(1) and (2)), which include cyanide compounds and are judged to be toxic (but when including others of the six kinds of toxic compounds besides cyanide compounds, those materials judged to be non-toxic), which have been incinerated with less than 15% ignition loss, can be disposed of in Marine Area B.

3). When sludge or authorized public sewerage sludge (materials described in 2-1(1) and (2)) which are judged to be toxic are solidified in concrete so that toxic materials included in the sludge will not leak, they may be disposed of in Marine Area A.

4). When sludge or authorized public sewerage sludge (materials described in 2-1(1) and (2)) which include mercury and mercuric compounds and are judged to be toxic, (but

when including others of the five toxic materials besides mercury and its compounds and cyanide compounds, materials judged to be non-toxic) are calcinated and thereby made non-toxic, they may be disposed of in Marine Area B.

5). Detoxified inorganic sludge (excluding water-soluble materials) and detoxified slag may be disposed of in Marine Area B.

6). Detoxified organic sludge, detoxified water soluble inorganic sludge, or detoxified acid or alkaline wastes may be disposed of in Marine Area C.

7). Even though materials may be sludge or acid or alkaline wastes which, according to articles 2) through 6) above, may be disposed of in the oceans,

(1). If materials are types of oils, or

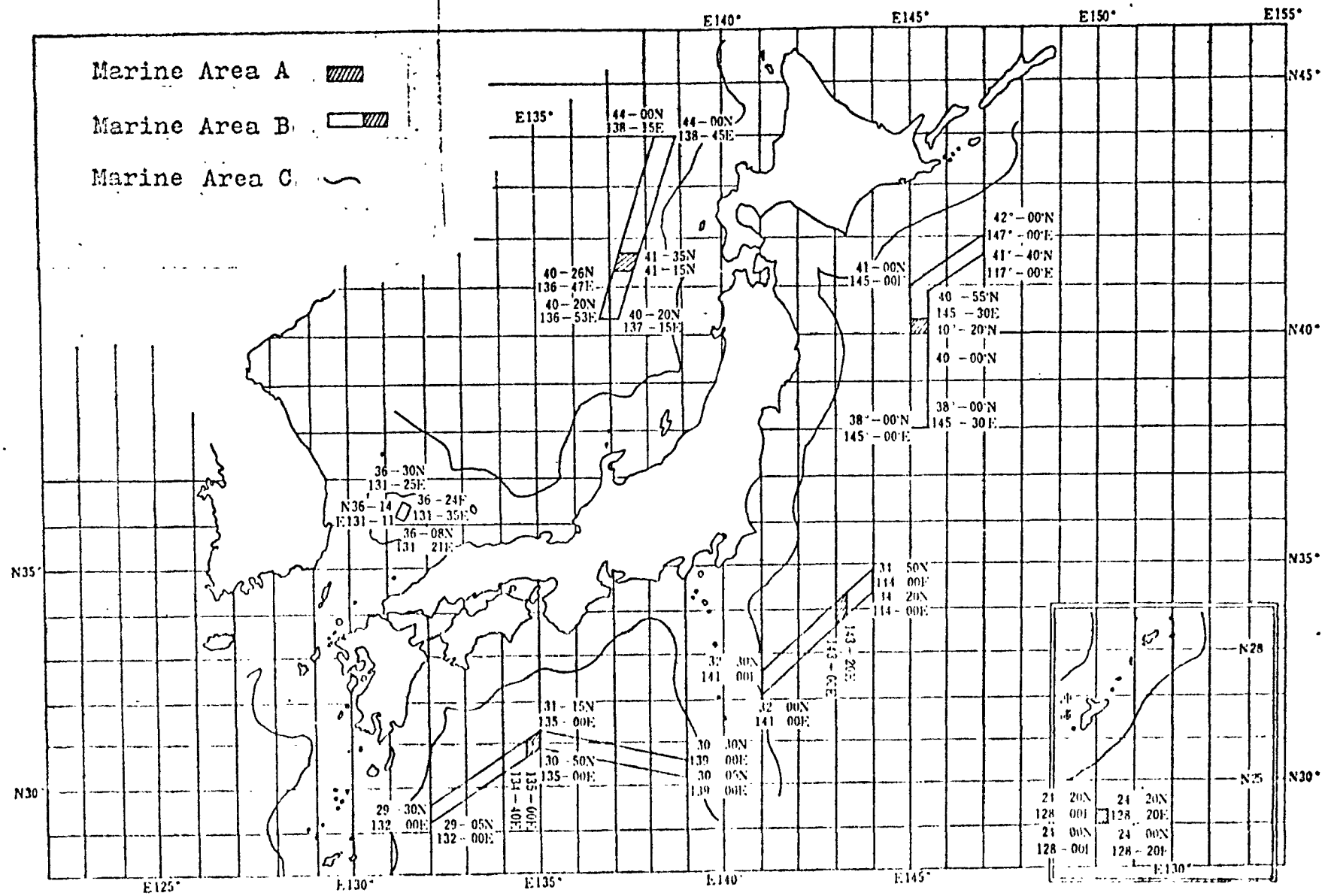
(2). If materials are discharges from a phenolic resin manufacturing industry and contain phenols,

they may not be disposed of in the oceans.

8). Marine Area A, Marine Area B, and Marine Area C, referred to in 2) through 6), will be called marine areas when indicated below.

The standards concerning methods of discharge when discharging wastes in any of the marine areas is as follows:

Discharge Area	Standards for Discharge Method	Related Standards	
Marine Area A	1. Specific gravity must be over 1.2 when discharging. 2. Discharge must not take place when vessel is moving.	Precautions must be taken which are necessary to insure that the wastes sink as quickly as possible, and that they accumulate as sediment.	Endeavor to avoid places where there is a fear of hindering the growth of marine flora and fauna.
Marine Area B	1. and 2. from above, and: 3. No discharge in powder form.		
Marine Area C	1. Discharge below the surface of the ocean. 2. Discharge while the vessel is moving.	Discharge waste in small quantities at a time and take necessary precautions to insure that the wastes diffuse in the ocean as quickly as possible.	


Marine Area A
Marine Area B
Marine Area C
E125°
E130°
E135°
E140°
E145°
E150°
E155°
N45°
N40°
N35°
N30°
N28
44 - 00N 138 - 15E
44 - 00N 138 - 45E
41 - 35N 41 - 15N
40 - 26N 136 - 47E
40 - 20N 136 - 53E
40 - 20N 137 - 15E
42° - 00'N 147° - 00'E
41° - 40'N 117° - 00'E
41 - 00N 145 - 00'
40 - 55'N 145 - 30E
40 - 00'N
38° - 00'N 145° - 00'E
38° - 00'N 145 - 30E
36 - 30N 131 - 25E
36 - 24E
N36 - 14 E131 - 11
131 - 35E
36 - 08N 131 - 21E
31 50N 114 00E
14 20N 114 - 00E
32 30N 141 00'
32 00N 141 00E
31 - 15N 135 - 00E
30 - 50N 135 - 00E
30 30N 139 00E
30 05N 139 00E
29 - 30N 132 00E
29 - 05N 132 - 00E
21 20N 128 001
24 20N 128 20E
24 00N 128 001
24 00N 128 - 20E

9). In general, even with industrial wastes which can be disposed of in the oceans, marine disposal should not occur when no special hindrance to landfill disposal can be found.

(3). Other Standards

1). Collection, transportation, and disposal of wastes should be carried out so that the wastes will not fly about or drift away.

2). The establishment of waste treatment facilities should be carried out in such a way that there is no fear of a rise of hindrances to the preservation of the environment in which we live.

3). Precautions should be taken so that there is no fear of wastes flying about, drifting away, or giving off offensive odors from transportation vehicles, receptacles, or pipelines.

2-3. Standards Established by Order of the Prime Minister's Office Concerning Toxic Industrial Wastes

The basic standards are those stated in 2-1, parts (1) to (3). In order to test wastes for levels of toxic materials, solubility tests are used for landfill disposal; for marine disposal, slag, inorganic authorized sewerage sludge, and inorganic sludge (excluding water soluble materials) are inspected by solubility tests, and organic sludge, water soluble inorganic sludge, and organic authorized public sewerage sludge are inspected by content tests. Acceptable values to be detected in such inspections are indicated in (1) and (2) below. The inspection methods will be described later in section 2-4.

(1). Standards for Acceptable Levels Detected by Solubility Tests

1	Alkyl Mercuric Compounds	No detection of alkyl mercuric compounds
	Mercury or Mercuric Compounds	No detection of mercury
2	Cadmium or Cadmium Compounds	In 1 l. of sample fluid, less than 0.3 mg. cadmium
3	Lead or Lead Compounds	In 1 l. of sample fluid, less than 3 mg. lead
4	Organic Phosphate Compounds	In 1 l. of sample fluid, less than 1 mg. organic phosphate

5	Cr^{+6} Compounds	In 1 l. of sample fluid, less than 1.5 mg. Cr^{+6}
6	Arsenic and Arsenic Compounds	In 1 l. of sample fluid, less than 1.5 mg. arsenic
7	Cyanide Compounds	In 1 l. of sample fluid, less than 1 mg. cyanide

(2). Standards for Acceptable Levels Detected by Content Tests

1	Alkyl Mercuric Compounds	No detection of alkyl mercuric compounds
	Mercury or Mercuric Compounds	In 1 kg. of test materials, less than 2 mg. mercury
2	Cadmium or Cadmium Compounds	In 1 kg. of test materials, less than 5 mg. cadmium
3	Lead or Lead Compounds	In 1 kg. test materials, less than 50 mg. lead
4	Organic Phosphate Compounds	In 1 kg. test materials, less than 5 mg. organic phosphate compounds
5	Cr^{+6} Compounds	In 1 kg. of test materials, less than 25 mg. Cr^{+6}
6	Arsenic and Arsenic Compounds	In 1 kg. of test materials, less than 25 mg. arsenic
7	Cyanide Compounds	In 1 kg. test materials, less than 5 mg. cyanide

2-4. Methods of Inspection of Toxic Materials Included In Industrial Wastes

Using solubility tests and content tests, inspection of toxic materials included in industrial wastes occurs according to the following procedures:

(1). Preparation of Sample Fluid for Solubility Tests

Preparation of Test Materials

1). Sludge ⟶ Sample as it is and remove foreign substances such as pebbles.

2). Materials Other than Sludge ⟶

Particle diameter less than 5 mm. ⟶ Sample as it is.

Other materials ⟶ Sample as they are, and after pulverizing, make particles larger than 0.5 mm. and smaller than 5 mm. by using sieves numbers 32 and 4.

Regulation of Test Fluids

1). Sludge for landfill disposal (excluding offshore land reclamation disposal), slag, or these materials treated for disposal ⟶

Mix the test materials (g.) and solvent (HCl or CO_2 added to pure water so that the pH is above 5.8 and below 6.3) (ml.) in a weight-volume ratio of 10%, and make more than 100 ml. of the fluid mixture.

2). Slag for offshore land reclamation disposal, sludge treated for disposal, slag solidified in concrete, sludge calcinated for marine disposal, or slag⟶

Mix the test material (g.) and solvent (NaOH, Na_2CO_3, or $NaHCO_3$ added to pure water so that the pH is above 7.8 and below 8.3) (ml.) in a weight-volume ratio of 10%, and make more than 100 ml.

3). Sludge made from slag treated for disposal in offshore land reclamation, sludge, and inorganic sludge for marine disposal (excluding water soluble materials)⟶

Add solvent (NaOH, Na_2CO_3, or $NaHCO_3$ added to pure water so that the pH is above 7.8 and below 8.3) to the test

materials so that there is a weight-volume ratio of 3% solid material (g.) included in the fluid mixture. (For solids included in sludge, use the weight of materials remaining after evaporation.

Solubility of Toxic Materials

Stir or shake continuously for 6 hours at normal temperature (about 20° C.) and normal pressure (about 1 atmosphere).

Preparation of Sample Fluids

Measure and take off the precise volume needed for examination from the supernatant of the liquid remaining after the solvent and test fluid have been filtered using Type 5-C filter paper and put in a centrifuge below 5000 rpm. for 20 minutes.

(2). Preparation of Sample Fluids for Content Tests

Preparation of Test Materials

Take up the test materials as they are into a beaker (500 ml. volume), and, using a non-metal spatula, crush the small lumps;

Regulation of Test Fluids

pass the homogeneous liquid through a synthetic fiber sieve (do not use a metal one) with 2 mm. apertures, then measure off the necessary volume (more than 200 g.) accurately from the liquid which passed through, pour it into a graduated cylinder with a cock attached (1 l. capacity) and add pure water to make 1 liter in all.

Preparation of Sample Fluid

1). In cases of sample fluid relating to sludge with a Cr^{+6} content⟶

Take off the necessary volume of sample fluid from the supernatant of the liquid remaining after the test liquid has been filtered through a glass filter and the solvent and test liquid have been centrifuged at less than 5000 rpm. for 20 minutes.

2). In cases using other materials⟶

After making the test fluid homogeneous by vigorously shaking and mixing it, quickly measure and remove the precise

amount needed for examination.

(3). Method of Examination of Sample Fluids

Abridged. (Corresponds to the method established by JIS).

(4). Calculation of Density

Solubility Tests	Sludge to be used for landfill disposal (excluding offshore land reclamation disposal) (limited to materials with a water content greater than 85%).	$C_1 = \frac{A}{V} \times \frac{15}{100-P} \times 10^3$
	Other materials	$C_1 = \frac{A}{V} \times 10^3$
Content Tests	Sludge (limited to materials with a water content of more than 95%).	$C_2 = \frac{A}{VxW} \times \frac{5}{100-P} \times 10^6$
	Other sludge	$C_2 = \frac{A}{VxW} \times 10^6$

Where:

A: Weight of toxic materials tested (mg.)

C_1: Density of toxic materials (number of mg. dissolved in 1 l. of sample fluid)

C_2: Density of toxic materials (number of mg. included in 1 kg. of test material)

P: Water content of test materials (%)

V: Volume of sample fluids (ml.)

W: Weight of test materials (g.)

3. Management of Disposed Household Appliances Which Contain Parts Which Utilize PCBs

3-1. History

Between 1954 and the end of 1971, about 53,000 tons of PCB were used in Japan, but the Kanemi PCB Poisoning Incident served as a turning point, and since 1971, there have been: (1) a ban on the use of PCB-containing carbonless copying paper; (2) a ban on reclamation use of PCB-containing carbonless copying paper; (3) a report concerning the circumstances of PCB use by makers of large machines such as transformers and condensers, and by users and importers, and instructions to make up records; (4) with a series of measures such as the suspension of production of transformers, condensers, and thermal media (August, 1972), a plan of countermeasure treatment concerning a large proportion of the intended use was formulated.

On the one hand, before the ban on use, 800 tons of PCBs were used in condensers in home electrical appliances; yet when we take into account their years of durability, it is estimated that at the present (1973) there is still about 540 tons in all households.

PCBs do not leak into the air or diffuse while household electrical appliances are in use; moreover, at present it is thought that there is no environmental contamination occurring because of the landfill and other types of disposal of discharged household electrical appliances which occur in all municipalities. Still, the Ministries of Health and Welfare, and International Trade and Industry carefully considered the tendency in disposal of household appliances from the present onward, and, in hopes of entirely preventing environmental contamination in the future, began in August 1973 to supervise local public organizations and related producing organizations in taking PCB-utilizing parts out of household electrical appliances which contain them prior to disposal.

3-2. The Products in Question

The products currently in question are limited to three kinds: television (both black and white and color), air conditioners, and electric ranges. The PCBs used in these three kinds of appliances make up 95% of all PCBs contained in all household electrical appliances. There are comparatively many large manu-

facturers of these items, and their organizations for the removal of parts containing PCBs are considered to be reliably structured.

3-3. Removal of Parts Containing PCBs

In principle, since long ago the municipalities were to carry out the collection, transportation, and disposal of waste household appliances, but in relation to the appliances which contain parts using PCBs:

(1). At the time of disposal, the removal of parts utilizing PCBs must occur in advance under the responsibility of the maker.

(2). The maker will store the removed PCB-utilizing parts for the present until an appropriate disposal method is decided upon. Still, since this does not include all household appliances in general use, for the purposes of distinguishing them, the Ministry of International Trade and Industry will compile a list of household electrical appliances which include PCBs.

The precise methods of removal of the PCB-

utilizing parts by the maker have been decided by conferences between the makers and local governments.

3-4. The precise methods for removal of the PCB-utilizing parts decided upon at the conferences of local governments and makers fall into the following two general types:

(1). A method by which the makers would be contacted by the municipalities and would examine and remove the parts at the place where they had been collected from the municipalities.

(2). A method by which the makers would be contacted by the consumers who want to dispose of the household electrical appliances, and, after examining whether there are any PCB-utilizing parts, and removing them if there are, the makers would attach a voucher in an easily visible part of the appliance to be disposed of.

Recent Aspects of Solid Waste Management in Japan

1974

Solid Waste Management Programs Division

Ministry of Health and Welfare

Japanese Government

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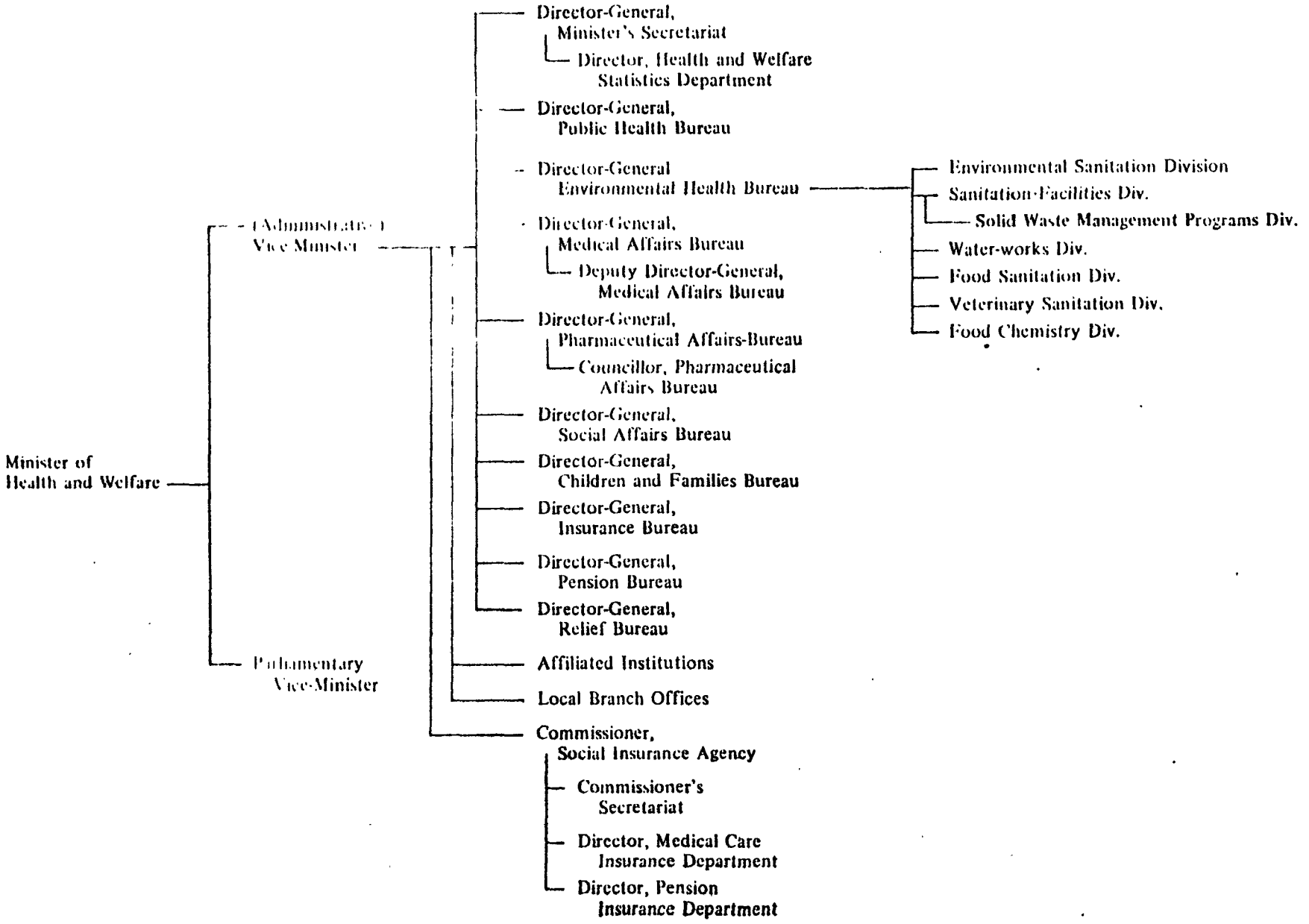
Organizational Chart of Ministry of Health and Welfare



Recent Aspect of Refuse Collection and Disposal (Actual Amount) – Gross National

Year (fiscal)	1962		1963		1964		1965		1966		1967		1968		1969		1970	
Population of Cleansing Service District	57,034,000		58,533,000		60,522,000		64,231,000		67,855,000		71,292,000		76,080,000		80,592,000		84,694,000 (82.5%)	
Total Discharge Amount of Refuse	28,433 t/d	100.0 %	35,900 t/d	100.0 %	40,045 t/d	100.0 %	44,522 t/d	100.0 %	48,340 t/d	100.0 %	53,825 t/d	100.0 %	62,005 t/d	100.0 %	70,115 t/d	100.0 %	76,998 t/d	100.0 %
Incineration	9,415	33.1	12,668	35.3	15,254	38.1	16,896	37.9	21,899	45.2	25,459	47.3	29,959	48.3	35,758	51.0	42,559	55.3
Sanitary Landfill (Land Reclamation)	11,802	41.5	15,140	42.2	16,176	40.4	17,659	39.6	16,594	34.3	20,292	37.7	22,470	36.2	24,688	35.3	27,715	33.5
Composting									706	1.5	753	1.4	770	1.3	677	1.0	548	0.7
used as Fertilizer	735	2.6	876	2.4	744	1.8	1,325	3.0	503	1.0	107	0.2	114	0.2	106	0.1	36	–
used as Fodder	341	1.2	271	0.7	224	0.6	252	0.6	287	0.6	215	0.4	145	0.2	102	0.1	96	0.1
Others	937	3.3	916	2.6	855	2.1	966	2.2	941	2.0	660	1.2	813	1.3	988	1.4	945	1.2
total	23,230	81.7	29,871	83.2	33,253	83.0	37,098	83.3	40,930	84.6	47,486	88.2	54,271	87.5	62,319	88.9	69,899	90.8
disposed by Inhabitants	5,203	18.3	6,029	15.8	6,792	17.0	7,424	16.7	7,410	15.4	6,339	11.8	7,734	12.5	7,796	11.1	7,099	9.2
Per capita Discharge Amount of Refuse	498 g/d		613 g/d		661 g/d		693 g/d		712 g/d		755 g/d		815 g/d		870 g/d		910 g/d	

Actual Investment for the Incineration Plants

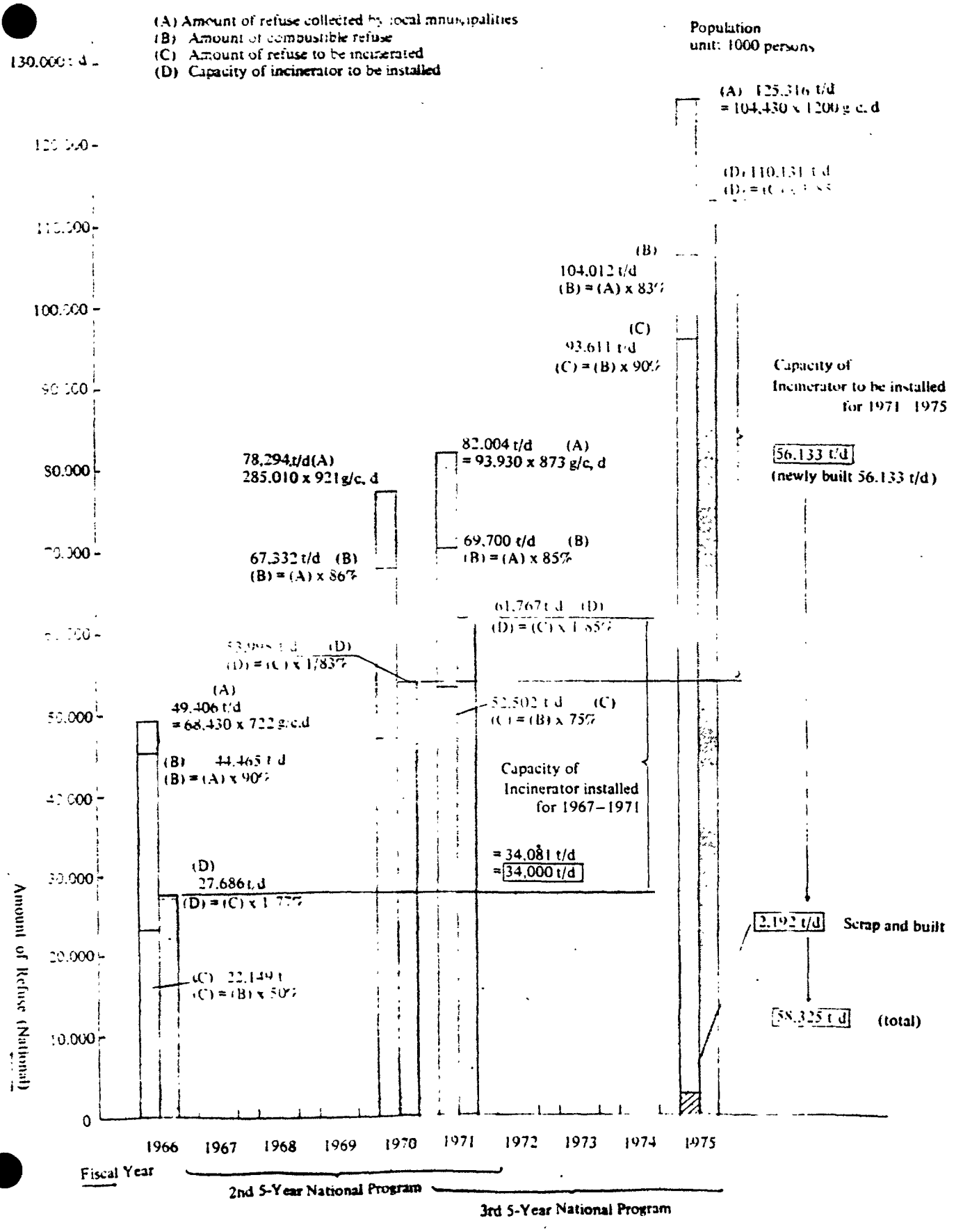
Fiscal Year	Number of Plants		Capacity of Plants (t/d)		Investment million ¥ (yen)			
	Total	The Total	Total	The Total	National Subsidy	Local Loan	Tax or Charge	Total
1963	117		2,728	14,901	94	2,553	1,871	4,518
1964	151		2,805	17,709	94	3,200	2,006	5,300
1965	152	473	3,027	20,736	94	6,700	3,206	10,000
1966	164	637	6,950	27,686	400	7,600	3,471	11,471
1967	149	786	5,120	33,361	600	9,200	3,800	13,600
1968	165	951	6,921	40,282	700	10,500	4,100	15,300
1969	159	1,110	6,900	47,182	830	11,000	4,070	15,900
1970	183	1,293	7,312	54,494 (53,898)	1,100	11,000	6,100	18,200
1971	179	1,472	10,477	64,375	2,220*	20,900	13,480	36,600
1972			13,200	77,575	4,350*	36,200	12,150	52,700

Cross National

Daily treating capacity	Number of Plants (1970)
Above 1 t/d, below 5 t/d.	172.
" 5 t/d, " 10 t/d.	298.
" 10 t/d, " 20 t/d.	268.
" 20 t/d, " 30 t/d.	133.
" 30 t/d, " 50 t/d.	141.
" 50 t/d, " 100 t/d.	134.
" 100 t/d, " 200 t/d.	76.
" 200 t/d, " 600 t/d.	57.
" 600 t/d, or larger	14.
Total	1,293.

* Incl. for refuse compressing or crushing plants.

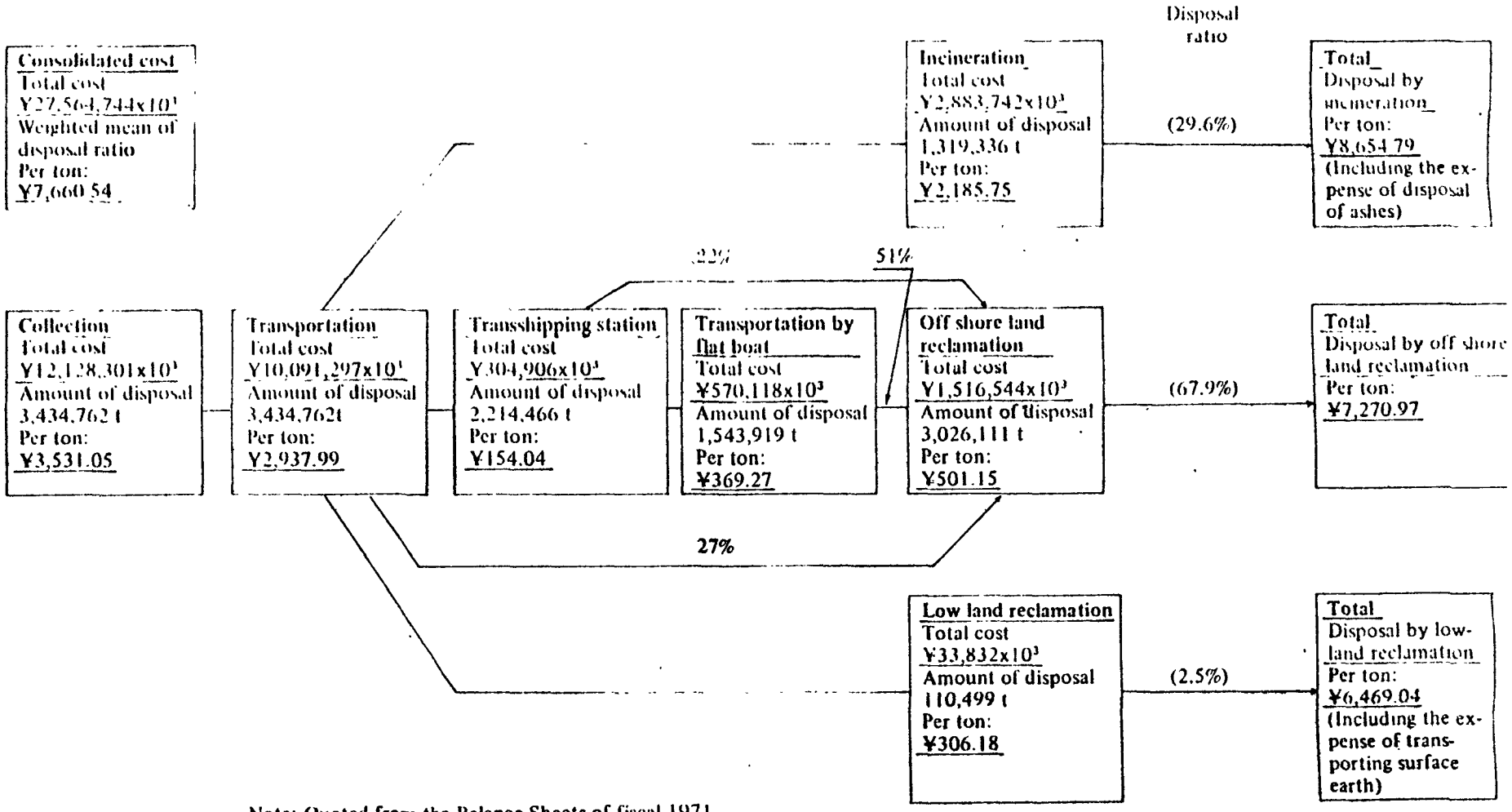
5-Year National Program for Installation of Refuse Incineration Plants



Composition of Refuse (Domestic) Tokyo Metropolitan Area

Fiscal Year	1963	1964	1965	1966	1967	1968	1969	1970	1971
Combustibles									
Paper	25.1	25.5	22.3	26.9	27.4	32.0	33.3	31.3	33.8
Plastics	2.0	3.3	3.8	5.4	4.6	7.3	9.7	10.3	8.0
Fibers	3.5	2.9	2.5	2.0	1.6	4.0	3.6	4.6	3.4
Wood & Bamboo	3.3	3.3	3.6	3.4	4.8	4.8	1.6	2.4	4.2
Rubber	1.4	0.5	1.1	1.4	0.8	1.2	0.8	1.5	0.6
Hides & Skins	0.9	0.7							
Straw	1.6	1.9	1.1	3.5	3.0	classified as "others"			
Grass & Leaves	2.1	3.2	2.5						
Vegetable refuse	31.1	36.3	44.2	31.9	31.0	32.8	31.8	31.5	26.6
Animal refuse	2.0	2.7	3.2	1.9	3.3				
Bread & Leftover	2.6	2.7	classified as "vegetable refuse"						
Others	-	-	-	-	-	6.1	6.7	6.8	5.7
Total	75.6	83.0	84.4	77.7	76.5	89.7	87.5	88.4	82.3
Incombustibles									
Metals	2.1	3.1	2.8	2.6	2.1	2.3	2.9	2.7	3.5
Glass	3.7	5.1	3.9	4.9	3.8	3.1	5.0	5.7	7.6
Chinaware					1.0	classified as "others"			
Shell	1.0	1.1	0.6	0.4	0.8				
Egg shell	1.4	0.8	1.0	1.4	0.6				
Earth & Sand	16.5	6.9	7.3	7.6	4.5				
Others	-	-	-	-	10.3	5.8	4.6	3.2	6.6
Total	24.4	17.0	15.6	22.3	23.5	10.3	12.5	11.6	17.7
Volumetric weight mt/m³	0.25	0.24	0.23	0.21	0.24	-	-		

CHART OF THE COSTS OF SOLID WASTE DISPOSAL (Tokyo Metropolitan Area) (Unit : Yen)



Note: Quoted from the Balance Sheets of fiscal 1971.

Refuse treatment plants operation or maintenance standards

The one who is going to construct a refuse treatment plant shall give notice to the governor (= prefectural governor) before the commencement of the construction as specified in the Ordinance of Ministry of Health and Welfare ..... Article 8-1*.

Refuse treatment plants shall be operated and maintained in accordance with the standards stipulated in the Ordinance of Ministry of Health and Welfare ..... Article 8-2*.

* Waste Disposal and Public Cleansing Law

Operation or Maintenance Standards

	Batch type Incinerator	Continuous type Incinerator	
Std. Operating Hour/day	8 hours	24 hours	
Combustion Temperature	over 400°C	700–1,000°C	
Quality of Ashes (Content of Volatile Solid)	less than 15%	less than 10%	
Quality of Exhausted Gas (1) Fine dust or soot	less than 0.7 g/Nm³	Cap. 200 t/d less than 0.7 g/Nm³	Cap. 200 t/d less than 0.2 g/Nm³
(2) Sulfer Oxide	$q = k \times 10^{-3} H_e^2$		

Stipulated in Air Pollution Control Law

Emission Standard of Sulfur Oxide

Prime Minister's Office Ordinance (Notification No. 1 June 22, 1971)
-- based on Air Pollution Control Law --

(Emission Standard of Sulfur Oxide)
Article 3

The standard limits for the discharge of sulfur oxide shall be its quantity calculated by the following formula;

$$q = K \times 10^{-3} H_e^2$$

The q, K and H_e in this formula present the following values;

q; The quantity of sulfur oxide
(in cubic meter per hour at 0°C and 1 atmospheric pressure)

K; 6.42 –22.2 (in cases of the existing facilities and plants, varies with local conditions ex. Tokyo 23 Wards K = 6.42)

K; 2.92---5.26 (in cases of the newly constructed facilities and plants, varies with local conditions ex. Tokyo 23 Wards K = 2.92)

H_e; The height of the outlet for discharge in meters corrected by the following formulae;

$$H_e = H_o + 0.65 (H_m + H_t)$$

$$H_m = 0.795 Q V / (1 + 2.58 / V)$$

$$H_t = 2.01 \times 10^{-3} Q (T - 288) \cdot (2.30 \log J + \frac{1}{J} - 1)$$

$$J = \frac{1}{\sqrt{QV}} (1460 - 296 \times \frac{V}{T - 288}) + 1$$

The H_e, H_o, Q, V and T in these formulae present the following values;

H_e; The height of the corrected outlet in meters
H_o; The actual height of the outlet in meters
Q; The volume of the discharged gas at 15°C in cubic meters per second
V; The speed of the discharged gas in meters per second
T; The temperature of the discharged gas at the absolute temperature

Disused Durable Consumer Products Collected in Fiscal 1971 by Yokohama City (from April 1971 to March 1972)

Type of Product	Specification	No. of Products Collected	No. of Prdts. per 1,000 households	No. of Households per prdt.	Weight (m.t.)	Distribution Ratio	
						No. of Prdts. (%)	Weight of Prdts. (%)
Electric Appliances	TV sets	14,536	9.4	106	285.1		
	Radio sets	8,906	5.8	173	53.2		
	Freezers	5,450	3.5	283	324.2		
	Washers	8,789	5.7	175	339.9	92,375	1,240.2
	Vaccum cleaners	8,018	5.2	192	82.0	(4.6 %)	(18.4 %)
	Warmers	7,582	4.9	203	45.0		
	Rice boilers	7,230	4.7	213	34.7		
	Fluorescent lamps	31,864	20.7	48	76.1		
Kitchen Utensils	Kerosene stoves & boilers	11,647	7.6	132	59.3	23,284	220.7
	Gas stoves & boilers	7,566	4.9	204	77.3	(1.2 %)	(3.3 %)
	Sinks	4,071	2.6	378	84.1		
Furniture	Mattresses	27,126	17.6	57	525.7		
	Tatami	12,393	8.0	124	367.4		
	Cabinets	13,741	8.9	112	409.1	184,710	2,192.3
	Tables, chairs, desks	48,351	31.4	32	479.8	(9.3 %)	(32.6 %)
	Fittings	83,099	54.0	19	410.3		
Vehicles	Bicycles	9,248	6.0	167	176.3	23,456	316.3
	Three-wheelers	8,157	5.3	189	81.7	(1.2 %)	(4.7 %)
	Baby carriages	6,051	3.9	255	58.3		
Others	Cans & bottles	765,091	497.0	2	902.1	1,666,230	2,760.4
	Other wastes	900,739	584.8	2	1,858.3	(83.7 %)	(41.0 %)
Total			1,292.1	1	6,729.7	1,990,055	6,729.9
						(100.0 %)	(100.0 %)

Amount of Industrial Wastes in Japan

Ministry of Health & Welfare
Unit: 1,000 t/year

Pref \ Wastes[1]	Sludge, Organic Residue 2) Animal Excreta	Waste Oil	Waste Plastics Waste Rubber	Waste Acid Waste Alkali	Waste Paper Wood Dust Waste Fabrics	Metal Dust Glass Dust Slags	Residual Ash Dust & Soot Concrete, Soil	Total	Fiscal year	Objects of Investigation 3) F	C	M	R	Remarks
Hokkaido	5,484	269	192	1,955	3,756	4,177	8,272	24,105	1971	o	o	o	o	
Aomori	1,580	47	4	146	318	466	811	3,372	1972	o	o	o	o	
Iwate	500	111	1	31	388	98	1,214	2,341	1972	o	o	o	o	
Miyagi	956	10	12	167	606	196	253	2,201	1971		o	o	o	
Akita	1,912	10	7	2	185	37	2,236	4,389	1971		o	o	o	
Yamagata	1,043	14	6	1	195	117	1,541	2,917	1961	o	o	o	o	
Fukushima	2,906	57	41	1,404	2,610	474	353	7,848	1970	o	o	o	o	
Ibaraki	1,086	52	58	404	627	1,413	2,911	6,554	1970 ~ 1	o	o	o	o	
Tochigi	1,786	10	13	50	177	195	1,480	3,713	1969	o	o	o	o	
Gunma	1,658	197	10	531	154	114	48	2,712	1970	o	o	o	o	
Saitama	86	116	26	665	340	525	3,842	5,601	1970		o	o		4)
Chiba	237	59	56	229	110	3,202	5,657	9,549	1969		o	o	o	
Tokyo	1,472	412	62	229	1,604	1,183	29,807	34,768	1969		o	o	o	
Kanagawa	3,345	194	127	4,500	861	399	25,879	35,305	1970	o	o	o	o	
Niigata	650	33	10	3,647	508	995	1,338	7,180	1971		o	o	o	
Toyama	619	16	10	162	306	1,294	633	3,040	1971		o	o	o	
Ishikawa	246	8	6	257	172	322	907	1,917	1971		o	o	o	
Fukui	811	159	8	22	162	60	359	1,581	1971	o	o	o	o	
Yamanashi	41	7	8	338	145	76	951	1,566	1971	o	o	o	o	
Nagano	3,198	24	18	947	93	62	115	4,457	1970	o	o	o	o	
Gifu	1,426	121	10	222	167	76	4,143	6,164	1970			o	o	
Shizuoka	394	83	36	826	851	280	23	2,493	1970				o	
Aichi	4,054	99	57	326	157	5,523	1,991	12,206	1970 ~ 2	o	o	o	o	
Mie	1,261	52	26	4	137	84	76	1,640	1969 ~ 71	o	o	o	o	
Shiga	256	50	15	273	266	95	515	1,470	1971	o		o	o	
Kyoto	426	3	6		132	55	2,907	3,527	1969	o	o	o	o	
Osaka	1,153	522	25	230	1,006	3,131	21,275	27,343	1968	o	o	o	o	4)
Hyogo	387	9	11	3	130	547	8,572	9,656	1969	o	o	o	o	
Nara	260		7		44	8	1,584	2,057	1968	o	o	o	o	
Wakayama	20	23	2	20	75	182	1,048	1,370	1970		o	o		
Tottori	825	2	1		149	33	154	1,164	1970	o	o	o	o	
Shimane	537	6	25	131	247	29	358	1,334	1971	o		o	o	
Okayama	611	11	15	348	56	3,432	179	4,659	1970	o	o	o	o	4)
Hiroshima	857	56	69	479	584	7,284	909	5,238	1970	o	o	o		
Yamaguchi	478	393	12	79	60	356	15,108	16,487	1969	o	o	o		
Tokushima	1,580	23	5	67	238	193	404	2,512	1972	o	o	o	o	
Kagawa	411	7	10	457	146	415	1,193	2,639	1971		o	o	o	
Ehime	1,787	459	19	169	380	966	2,476	6,255	1971	o	o	o	o	
Kochi	414	1	9	15	113	160	246	938	1970	o	o	o	o	
Fukuoka	1,438	72	31	867	237	6,762	1,506	10,913	1971		o	o	o	
Saga	1,316	5	20	1,500	366	131	3,856	7,190	1972	o	o	o	o	
Nagasaki	Under investigation													
Kumamoto	918	13	13	681	1,740	198	557	4,120	1972	o	o	o	o	
Oita	1,690	40	14	84	307	1,584	4,651	8,370	1972	o	o	o	o	
Miyazaki	3,065	95	165	606	60	437	495	4,923	1971	o	o	o	o	
Kagoshima	Under investigation													
Okinawa	Under investigation													

1) There are some differences in definition of wastes among prefectures.
2) Useless objects in solid state relating to animals or vegetables, used as raw materials.
3) F: Farming C: Construction M: Manufacturing R: The rest
4) Not for entire area of Prefecture.

Environmental Water Quality Standards relating to Human Health

Item	Standard Values[1]
Cyanide	not detectable
Alkyl Mercury	not detectable
Organic phosphorus[2]	not detectable
Cadmium	0.01 ppm or less
Lead	0.1 ppm or less
Chromium (Sexivalent)	0.05 ppm or less
Arsenic	0.05 ppm or less
Total Mercury	not detectable

1 Maximum values.

2 Organic phosphorus includes parathion, methyl parathion, methyl demeton and E.P.N.

Environmental Water Quality Standards relating to the Living Environment

1. Rivers

Category	Item	Standard Values[1]				
		pH	Biochemical Oxygen Demand (BOD)	Suspended Solids (SS)	Dissolved Oxygen (DO)	Number of Coliform Groups
AA	Water supply, class 1, conservation of natural environment and uses listed in A ~ E	6.5~8.5	1 ppm or less	25 ppm or less	7.5 ppm or more	50 MPN/100 ml or less
A	Water supply, class 2; Fishery, class 1; Bathing and uses listed in B ~ E	6.5~8.5	2 ppm or less	25 ppm or less	7.5 ppm or more	1000 MPN/100 ml or less
B	Water supply, class 3; Fishery, class 2, and uses listed in C ~ E	6.5~8.5	3 ppm or less	25 ppm or less	5 ppm or more	5000 MPN/100 ml or less
C	Fishery, class 3; Industrial water, class 1, and uses listed in D ~ E	6.5~8.5	5 ppm or less	50 ppm or less	5 ppm or more	
D	Industrial water, class 2; Agricultural water[2], and uses listed in E	6.0~8.5	8 ppm or less	100 ppm or less	2 ppm or more	
E	Industrial water, class 3; Conservation of Environment	6.0~8.5	10 ppm or less	Floating matter such as garbage should not be observed	2 ppm or more	

[1] The standard value is based on the daily average value. (The same applies to the standard values of lakes and sea waters.)
[2] At the inlet of agricultural water, pH shall be between 6.0 and 7.5 and dissolved oxygen shall not be less than 5 ppm. (The same applies to the standard values of lakes.)

Notes: 1. Conservation of natural environment: Conservation of scenic spots and other natural resources.
2. Water supply, class 1: Water treated by simple cleaning operation, such as filtration.
Water supply, class 2: Water treated by normal cleaning operation such as sedimentation and filtration.
Water supply, class 3: Water treated through a highly sophisticated cleaning operation including pre-treatment.
3. Fishery, class 1: For aquatic life, such as trout and bull trout inhabiting oligosaprobic water, and those of fishery class 2 and class 3.
Fishery, class 2: For aquatic life, such as fish of the salmon family and sweetfish inhabiting oligosaprobic water, and those of fishery class 3.
Fishery, class 3: For aquatic life such as carp and silver carp inhabiting β-medium rotten water.
4. Industrial water, class 1: Water given normal cleaning treatment such as sedimentation.
Industrial water, class 2: Water given sophisticated treatment by chemicals.
Industrial water, class 3: Water given special cleaning treatment.
5. Conservation of environment: Up to the limits at which unpleasantness is caused to the people near-by in their daily life (including, walk by the riverside, etc.)

2. Lakes (natural lakes, reservoirs and marshes with more than 10 million cubic meters of water.)

Category	Item	Standard Values				
		pH	Chemical Oxygen Demand (COD)	Suspended Solids[1] (SS)	Dissolved Oxygen (DO)	Number of Coliform Groups
AA	Water supply, class 1, Fishery, class 1; conservation of natural environment uses and listed in A - C	6.5–8.5	1 ppm or less	1 ppm or less	7.5 ppm or more	50 MPN/100 ml or less
A	Water supply, class 2 and 3; Fishery, class 2, Bathing and uses listed in B - C	6.5–8.5	3 ppm or less	5 ppm or less	7.5 ppm or more	1000 MPN/100 ml or less
B	Fishery, class 3; Industrial water, class 1; Agricultural water, and uses listed in C	6.5–8.5	5 ppm or less	15 ppm or less	5 ppm or more	
C	Industrial water, class 2, Conservation of environment	6.0–8.5	8 ppm or less	Floating matter as garbage shall not be observed.	2 ppm or more	

[1] With regard to fishery, classes 1, 2 and 3, the standard value for suspended solids shall not be applied for the time being.

Note: See notes for Rivers.

3. Coastal Waters

Category	Item	Standard Values: pH	Chemical Oxygen Demand (COD)	Dissolved Oxygen (DO)	Number of Coliform Groups[1]	N-Hexane Extracts
A	Fishery, class 1; Bathing and uses listed in B, C	7.8 - 8.3	2 ppm or less	7.5 ppm or more	1000 MPN/100 ml or less	not detectable
B	Fishery, class 2; Industrial water and uses listed in C	7.8 - 8.3	3 ppm or less	5 ppm or more		not detectable
C	Conservation of environment	7.0 - 8.3	8 ppm or less	2 ppm or more		

[1] With regard to the quality of fishery, class 1 for cultivation of oisters, the number of coliform groups shall be less than 70 MPN/100ml.

Notes: 1. Fishery, class 1: For aquatic life such as red sea-bream, yellow tail, seaweed and those of fishery,
Fishery, class 2: For aquatic life such as gray mullet, laver, etc.

2. Conservation of environment: Up to the limits where no unpleasantness is caused to people in daily living (including a walk by the shore, etc.).

Strictly decided standards

* The prefectural government is entitled to decide more strict standards of effluent in its regulations by Water Pollution Control Law.**

** Water Pollution Control Law

Article 3

1. The standards of an effluent shall be provided for in the Prime Minister's Office Order (including pollution by heat, the same hereinafter)

3. If there is any Public-Use Water Area*** belonging to the prefectural jurisdiction for which the effluent standards as provided for in paragraph 1 is recognized to be insufficient for protecting human health and for preserving the living environment in its regulations than the permissible extent shown in the effluent standards as provided for aforementioned paragraph by enacting necessary prefectural regulations in accordance with the standards provided for in Cabinet Order.

*** Public-Use Water Area

The water areas in public use such as rivers, lakes, ports and harbors, coastal seas, etc., including their connected water ways such as public water ways, irrigation water ways and other water ways placed to public use.

Example

Effluent Standards: Items related to the Protection of the Living Environment (Strictly decided by Tokyo Metropolitan Government)
Applying for all the effluent discharging into Tama River

pH	5.8–8.6	
BOD	25 mg/l	(daily average 20 mg/l)
COD ($K_2Cr_2O_7$)	40 mg/l	(daily average 30 mg/l)
SS	90 mg/l	(daily average 70 mg/l)
N-hexane extracts	5 mg/l	(mineral oil)
	5 mg/l	(animal and vegetable fats)
Phenols	1 mg/l	
Copper	1 mg/l	
Zinc	5 mg/l	
Dissolved iron	10 mg/l	
Dissolevd manganese	10 mg/l	
Chrome	2 mg/l	
Flourine	15 mg/l	
Number of coliform groups (per cc)	3,000	(daily average)

Effluent Standards: Substances related to the Protection of Human Health

Toxic Substances	Permissible Limits
Cadmium and its compounds	0.1 mg/l
Cyanide compounds	1 mg/l
Organic phosphorus compounds (parathion, methyl parathion methyl demeton and EPN only)	1 mg/l
Lead and its compounds	1 mg/l
Sexivalent chrome compounds	0.5 mg/l
Arsenic and its compounds	0.5 mg/l
Total mercury	Not detectable[1]
Alkyl mercury compounds	Not detectable[1]

[1] By the term "not detectable" is meant that when the effluent is examined by the method designated by the Director General of the Environment Agency, the result of the examination is below the fixed amount limit of said method.

Effluent Standards: Items related to the Protection of the Living Environment

Item	Permissible Limits
pH	5.8~8.6 for effluent discharged into public water bodies other than coastal waters
	5.0~9.0 for effluent discharged into coastal waters
BOD, COD	160 mg/l (daily average 120 mg/l)
SS	200 mg/l (daily average 150 mg/l)
N-hexane extracts	5 mg/l (mineral oil)
	30 mg/l (animal and vegetable fats)
Phenols	5 mg/l
Copper	3 mg/l
Zinc	5 mg/l
Dissolved iron	10 mg/l
Dissolved manganese	10 mg/l
Chrome	2 mg/l
Fluorine	15 mg/l
Number of coliform groups (per cc)	3,000 (daily average)

Notes: 1. The discharge standards in this table are applied to the effluents from industrial plants and otehr places of business whose volume of effluents per day is not less than 50 m^3.

2. The discharge standards for pH and the content of dissolved iron are not applied to the effluents from industrial plants and other places of business engaged in sulphur mining or processing including mining for iron sulphide ore coexistent with sulphur.

3. The discharge standards for BOD are applied to public waters other than coastal waters and lakes, while the discharge standards for COD are applied only to effluents discharged into coastal waters and lakes.

The paper to be presented to:
"The Second Japan-U.S. Conference on Solid Waste Management"
September, 1974, Washington, D.C., U.S.A.

XV

RESOURCE RECOVERY FROM MUNICIPAL SOLID WASTE IN JAPAN

by

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August, 1974

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DRAFT
TRANSLATION
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ABSTRACT

The paper consists of essentially two parts; the first deals with a general overview on resource recovery in Japan, and the second with the resource recovery research and development project currently underway at the Agency of Industrial Science & Technology, M.I.T.I.

In the first part, the historical background on the resource recovery concept in Japan is reviewed, which then is followed by the current status and future trends with particular emphasis on legal, social, institutional and economic aspects. Recent technological developments of processing system aimed at resource recovery from the Japanese municipal refuse are also reviewed and some problems regarding the technology encountered in the effort are described. In addition, an assessment of impacts of resource recovery on the municipality and the country as a whole are discussed.

In the second part, AIST's Resource Recovery Project is described in detail: Firstly, the basic project concept with its objectives, Agency's responsibilities, the R & D organization and the financing summarized is presented. Secondly, the R & D program areas are reviewed with the specific aim for each research theme. Thirdly, as the project is in its second year of Phase I term, current progress and some important results obtained from the feasibility studies on the selected research topics are stated and an interim evaluation is made. Finally, currently proposed Phase II term of the Project, which shall start with the FY 1976 and last for three to five years is briefed to give some idea on what the Agency expects before the resource recovery system is transferred to the municipality and implemented in this country.

Phase II of the Project is essentially a demonstration of alternative prototype resource recovery systems under the Japanese socio-economical circumstances for the effective future implementation.

Some concluding remarks based on our AIST's project management are also presented.

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RESOURCE RECOVERY FROM MUNICIPAL SOLID WASTE IN JAPAN

by

Sukehiro GOTOH and Michio NAKAJIKU*

The present report discusses, among various problems regarding the solid waste, recovery of materials and energy resources out of municipal solid wastes. The discussion restricts itself to the resource recovery aspect and will only cover the collection and disposal whenever the necessity arises.

On the occasion of the First Conference in Tokyo, Mr. John P. Lehman, of U.S. Environmental Protection Agency, presented a report entitled "Resource Recovery: An Assessment", and we were given a good opportunity to grasp a wide variety of activities and efforts being made in the resource recovery field in the United States. In response to Mr. Lehman's paper, a brief comment was made, at the time, by (late) Mr. Ryosaku Shimizu of Japanese Agency of Science & Technology. In this comment, Mr. Shimizu pointed out that the systems approach to the problem which he considered most important was lacking in the Japanese effort.

Based on these discussions of the First Conference, this paper reports, in the resource recovery field in Japan, what have been done so far, how is the current status, what are the problems and what are being planned now.

The paper consists of the following subjects. In the first part, an outline of resource recovery and reuse will be presented: Various efforts from local autonomous, consumers, central government and industry sectors are summarized. And then problems and barriers to resource recovery identified in this country will be discussed

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with emphasis first on the technological and secondly on non-technological aspect.

In the latter half of the paper, AIST's effort since the FY 1972 is summarized: This is an essentially technological R & D effort of the central Government, although its related sccio-economical matters and the impacts assessments are ccncurrently dealt with in order to implement the system effectively. Emphasis is thus placed on the comprehensive treatment of the subject.

I. GENERAL OVERVIEW OF RESOURCE RECOVERY IN JAPAN

BACKGROUND

As in the United States, resource recovery, or recycling, in Japan has taken various forms in the past. Let us call this stagewise change in the recycling form as "a level of recycling". The lowest level of recycling, by which we mean, for example, returning bottles to the food or liquor store, or selling bundles of old newsprint, cloths, bottles, or the likes to a ragman, has long been and is now practised in every city or town. At this level, one does not need any special systematized effort, instead simply follows the tradition of the society with a little effort. To some extent, however, it is said that this depends on the life style or more general value concept of those days. In Japan, the idea to use things effectively and repeatedly was once considered a virtue and the public awareness on the scarcity of natural resources in this island country enhanced the idea. At least, this was very true till the end of the World War II. And for another decade or so in the postwar society before Japan emerged as an industrial country in the world, this life style had been still considered a virtue.

For the past 10 to 15 years, however, this level of recycling has been diminishing gradually, almost without being noticed. This period of time turns out to have been the time when mass production and mass consumption in Japan started and were actually taking its shape, and concurrently the per capita GNP or income, or labor cost was sharply increasing. This general circumstances and change in public awareness unfavored the recycling and, because of higher costs of repairing or storing, one started discarding such things as once unthinkable; refrigerators, TV sets, relatively new furnitures, etc.

Table 1 shows an increase in the daily percapita production of municipal solid waste (national average) as compared with changes in the total population and net GNP values. It is known that the percapita generation is strongly related to the net GNP, whose linear relationship was confirmed. Along with this large growth rate of percapita waste generation during this period, a sharp change in the waste composition, both physical and chemical, was observed. This change owed to the fact that the collected waste contained more and more plastics, bulky wastes, mingling industrial wastes and other newer (and normally hard-to-treat and dispose) materials.

With all this historical background, little attention has been paid, till recently, on much higher levels of recycling or reclaimation, such as heat reuse and electric generation out of waste, materials extraction (paper fibers, ferrous and nonferrous metals, etc.) from mixed collected waste stream, or incinerator residues processing.

Only exception for this level of recycling is the high-speed mechanical composting, which is a conversion-type resource reclamation from mixed municipal waste. As early as back in 1956, and for the following ten years, more than 30 plants for composting had been constructed and operated successfully in Japan. However, by the end of 1971, the number of plants was counted only 28, of which mostly suffered from economical problems. As now, seven plants remain barely in the whole country.

Although it is anticipated that the composting will come into the light again by many people, this past failure appears to be predominantly economical; especially in contrast with chemical fertilizers. Farmers once were heard to be complaining about contamination of compost with such non-compostables as glass or plastics.

TABLE 1 YEARLY CHANGE IN AVERAGE PER CAPITA WASTE GENERATION

Year	National Population (10^4)	Average Per Capita Generation (g)	GNP (Net) (billion yens)
1960	9,388	514	20,348
1961	9,473	491	24,275
1962	9,561	498	24,610
1963	9,654	613	27,783
1964	9,748	660	30,788
1965	9,840	695	32,451
1966	9,932	712	36,286
1967	10,018	755	41,140
1968	10,131	815	46,734
1969	10,257	870	52,522
1970	10,372	910	57,441
1971	10,454	960	60,728

Source: Ministry of Health & Welfare Data

Nevertheless, the need for resource recovery at various levels is increasingly emphasized, as the newer value concept based on essentially such idea as "the Spaceship Earth" is becoming accepted in this country. To illustrate one aspect of this need, a macroscopic material balance is given in Table 2. This shows that, in 1971, Japan imported (raw) materials of various kinds including foods and oils with an amount of 500 million tons* and exports of products totalled to 45 million tons; which, in turn, means the difference of ca. 400 million tons were being deposited in various forms of material or waste in this country.

Waste Disposal and Public Cleansing Law

When discussing resource recovery from municipal waste, one has to refer to this law as the sole national law on the waste handling in Japan. The Law passed in the National Diet (Japanese Parliament) in December, 1970 and was enacted in September, 1971, with the accompaning working rules of related governmental agencies. The waste, according to the Law, is legally divided into two categories; the industrial and the general waste. Further, responsibilities for treatment of the former are assumed for the enterpreneur in charge of the emission, while the latter is for the municipal authority. However, in practice, some amount of industrial waste is mingled with the normal general waste and is hauled by the municipality. Thus the term "municipal waste" or simply "unburn refuge", although it is not defined in any form in the Law, is commonly used and understood as the waste which is actually hauled and disposed of by the municipality.

The Law, as its title partially indicates, is a revision of the formerly known "Public Cleansing Law". With this revision, an important point is that the Law now classifies the wastes and assumes the responsibility for their disposal, although there is

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* A ton in this report is in the metric unit or equivalent to 1,000 Kgs (ca. 2,200 lbs).

TABLE 2 MATERIAL TRADE BALANCE

(Import) 10^8 tons

Foods	0.2
Iron Ore	1.2
Other Metal Ores	0.2
Other Minerals	0.4
Crude Oil	2.3
Coal	0.5
Others	0.2
Total	5.0

(Export) 10^8 tons

Steel	0.24
Fertilizer	0.04
Cement	0.02
Foods	0.02
Textiles	0.02
Ships	0.06
Other Products	0.05
Total	0.45

no specific instructions or incentives for resource recovery involved with. For the municipality, the Law authorizes exemption from the direct disposal of the industrial waste, which is generally considered a new development in a legal sense.

From Disposal to Resource Recovery

Traditional handling of municipal refuge, as indicated in the Disposal Law, has never intended a higher level recycling until very recently. However, the need for resource recovery observed for the last couple of years, arose first from the municipality sector, then from consumers and now is positively supported by the industry sector. At a recent meeting of the National Federation of Municipal Authorities for Public Cleansing (whose member municipalities are counted 498), a resolution for promoting technology development of resource recovery was made formally.

The reasons that the municipality first came for resource recovery appear to be as follows: Firstly, the municipality with the traditional disposal of incineration or landfilling became simply not manageable with the increasing amount of complex-in-composition refuse, by both financial and technological means. Secondly, the citizen's awareness for resource recovery instead of disposing the waste has been giving constant pressures to the municipality. These two reasons have together formed the following trends.

- Consumer's and citizen's increasing desire for higher quality of the environment, has made the municipality aware of that any simple disposal method which is (even) environmentally acceptable will no longer practical.

- The municipality has thus realized that any such processing

costs a lot: With incineration, the facilities for air pollution control, water treatment and residues disposal satisfying ever getting severer emission standards are costly. Similarly, with landfilling, costs for abatement of odor, soil pollution, vibrations, noises, traffic jam of hauling vehicles and other adverse effects are staggering.

- Land purchasing for disposal or processing has become increasingly difficult for the municipality because of neighborhood's opposition and the increase of land price.

- Public awareness of scarcity of natural resources in this country has increased recently, especially after the Arab Oil Embargo last autumn.

- Industries who have been concerned mainly with recycling of industrial wastes alone, now have turned their attention ~~to resource~~ recovery from municipal refuse.

- Government, throught various agencies, has started diversified efforts for resource recovery, based on the national interest for protection of resources depletion and from foreign countries' threats on the diplomatic stage.

CURRENT STATUS AND TRENDS

Japanese Municipal Waste for Resource Recovery

As it is so in Europe and the United States, the composition and other characteristics of the Japanese waste are subject to greater change with seasons and locality. It is important to grasp those variations no matter what type of recycling is intended.

A typical example of a yearly averaged composition of the Japanese municipal refuse is shown in Table 3. This is the average composition of the waste collected in Tokyo Metropolitan area in 1972 with the averaged moisture content (in percentage) for each entry. Compared with the composition of the American refuse, the followings are noteworthy for the Japanese waste on the average sense.

- Overall moisture content is approximately twice as much higher.
- Plastic content is 2 to 3 times more.
- Food waste which is normally very much wet, occupies relatively higher content.
- Metals fraction is about half that of the American refuse.
- Paper fraction is also relatively lower.

Because of these relative features, the Japanese waste has, on the average, a heating value of 1,300 Kcal/kg; generally ranging from 1,000 to 1,500 Kcal/kg. Although the carolic value tends to increase, this relatively lower heating value is considered a disadvantage especially for energy recovery from the Japanese municipal waste.

TABLE 3 REFUSE COMPOSITION AND ITS AVERAGE MOISTURE CONTENT - TOKYO METROPOLITAN AREA IN 1972

	Composition	Weight Percent (Wet Base)	Av. Moisture Content, Percent
Combustible	Paper Products	38.2	51.8
	Plastics	7.3	36.6
	Textiles	3.6	44.6
	Woods, Bamboo	4.2	41.7
	Rubbers, Leather	0.5	13.0
	Garbage (Food Waste)	22.7	76.3
	Other Organics	5.7	55.5
Non-combustible	Metals	4.1	5.7
	Glass, Ceramics	7.1	1.2
	Other Inorganics	6.6	-

TABLE 4 ULTIMATE ANALYSIS AND HEATING VALUE OF THE COMBUSTIBLE

Carbon (C)	Hydrogen (H)	Oxygen (O)	Sulfur (S)	Nitrogen (N)	Heating Value Kcal/Kg
51.8 %	2[illegible] %	38 %	0.1 %	2.6 %	4,753

Source: Nomal Haibutsu (Solid Waste), September, 1973.

The combustible fraction which can be the raw material for the "back-end system" like pyrolysis has, however, a comparable chemical composition. An ultimate analysis is illustrated in Table 4. The heating value of this combustible for this example was 4755 Kcal/kg (dry base), which is, together with its chemical composition, approximately equal to those of the combustible fractions of European and American refuge. This suffices to say that the large part of the combustibles is cellulosic no matter where the refuse comes.

In conclusion, the Japanese waste is handicapped in that the pretreatment of separating the organics from inorganics requires a more complicated, thus costly processing.

Almost all present consumer goods or products are considered the potential input to the municipal waste processing. Thus whatever type of resource recovery may be intended, the current statistics on those materials and products are of relevant importance. Furthermore, the data may become important for predicting the change in the future refuse composition and the possibility of success for the present source separation for facilitating the recycling. At present, source separation practiced in the Tokyo Metropolitan (Special District) areas, for example, requires the housewife to separate the waste into three categories; the normal waste, hard-for-disposal waste such as plastics or non-combustibles and bulky matters. The first two types of waste are picked up daily or every other day, while the bulky wastes are hauled less frequently; usually once every two weeks or so.

In Table 5, six important materials or products were selected, that might result in the potential effects on the municipal waste composition. They are (1) automobiles, (2) paper, (3) plastics, (4) home electric appliances, (5) metal cans and (6) glass bottles.

TABLE 5 MAJOR WASTE PRODUCTS

(1) Junk Cars (Unit: 10^3 cars)

FY	1972	'73 (E)	'74 (E)	'75 (E)	'76 (E)
Number of Cars Owned A	22,930	25,299	27,502	29,530	31,377
Abandoned Cars B	1,980	2,610	3,000	3,360	3,680
B/A (%)	8.6	10.32	10.91	11.38	11.73

E: Estimated

(2) Paper Stock (Unit: 10^3 tons)

FY	1972	'73 (E)	'74 (E)	'75 (E)	'76 (E)
Production A	13,648	15,800	16,700	17,000	18,000
Recycled W. Paper B	5,131	6,000	6,600	7,200	7,600
City Source	3,591	4,200	4,600	5,000	5,300
Industry Source	1,540	1,800	2,000	2,200	2,300
B/A (%)	37.60	37.96	39.52	42.35	42.22
C/B (%)	69.99	70.00	69.70	69.44	69.74

E: Estimated

(3) Plastics

(Unit: 10^4 tons)

FY	1972	'73 (E)	'74 (E)	'75 (E)	'76 (E)
Production A	565.7	58.51	628.7	677.6	731.8
Waste Plastics B	111.6	166.2	203.7	235.1	258.9
Household Source C	84.0	94.2	105.9	119.0	131.4
B/A (%)	29.45	31.82	33.36	34.70	35.38
C/B (%)	50.42	50.59	50.50	50.62	50.75

E: Estimated

(4) Waste Home Electric Appliances

(Unit: 10^4 units)

FY	1972	'73 (E)	1974 (E)		'75 (E)	'76 (E)
			Production	Waste		
Refrigerator	161	188	330	209	228	248
Washing Machine	245	266	415	283	303	326
Vacuum Cleaner	125	135	320	153	175	196
Air Conditioner	13	19	280	27	38	54
TV Set (B & W)	347	333	116	314	290	258
TV Set (Color)	76	132	300	204	280	373
Stereo Equipment	81	91	175	102	114	125
Electronic Heating Range	1	2	110	4	6	10

E: Estimated

(5) Cans (Production)

FY	1972	'73 (E)	'74 (E)	'75 (E)	'76 (E)
Steel Can (10^3 tons)	83	176	289	390	450
Aluminum Can (10^6 cans)	160	617	1,651	1,853	2,000

E: Estimated

(6) Glass Container (Unit: tons)

FY	1972	'73 (E)	'74 (E)	'75 (E)	'76 (E)
Production A	1,843,970	1,900,000	2,000,000	2,100,000	2,200,000
Waste Bottles B	553,191	570,000	600,000	630,000	660,000
Household Source C	331,915	342,000	360,000	378,000	396,000
B/A (%)	30.00	30.00	30.00	30.00	30.00
C/B (%)	60.00	60.00	60.00	60.00	60.00

Source: Each Table based on the MITI statistics.

For the all products, except metal cans, yearly statistical figures on both production and disposal are listed.

The automobiles abandoned on the street, for example, call now public attention, and who is actually responsible and who should pay for taking care of is a central controversy among the municipal authority, automobile manufacturers, and the residents. Considering the fact that the municipal sanitation department is not capable of disposing or recycling of those cars, the future of this problem is hardly predicable.

For papers, the recycle ratio (recycled amount/production) instead of waste paper amount is listed. The figure of 38 percent recycle ratio already observed in 1972, is almost two times the corresponding American figure of 19 percent in 1967, which was reported last year at the First Conference. As predicted in this table, the ratio is expected to still increase at least nearly by 5 percent two years from now. Further we are optimistic for this: Recent technological development by the AIST, which shall be described later, has made possible to recover reusable paper fraction out of the mixed refuse mechanically in the most efficient and effective manner. When the equipment being installed in the near future on an extensive scale, the paper recycle ratio is expected to increase further more, perhaps reaching somewhat 55 percent or more.

As for the plastics, only the waste fraction is indicated. Recent MITI's data show, however, that, in 1973, 163,000 tons out of 1,862,000 tons of the waste plastics (approximately 9 percent) were recycled in one form or another. Current estimate for the plastic recycling based on the data gives 523,000 tons of 2,589,000 waste tons in 1976, which corresponds to about 20 percent.

Municipality's Trends for Resource Recovery

As stated before, no specific effort for resource recovery by the municipality has been observed except the high-speed composting.

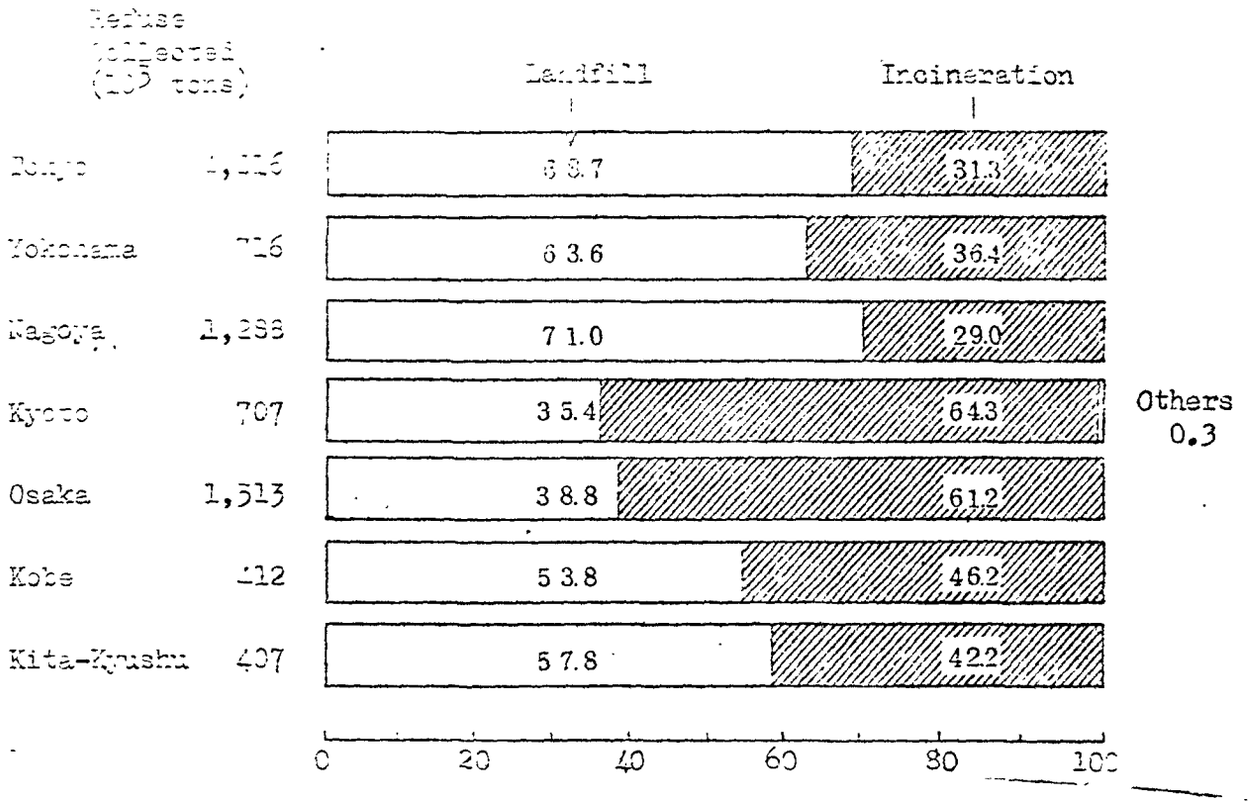
Future trends, however, include many possibilities for the Japanese municipality. Most promising one for earlier realization is heat recovery by incineration. This possibility may be especially higher for large cities, where large scale-incineration is actually in practice. On a national basis, transfer from landfilling to incineration in refuge disposal has been enhanced by the Ministry of Health and Welfare through its First (FY 1963 - FY 1967) and Second (FY 1967 - FY 1971) Five-Year Plans for Incineration. During the period, a large number of quality incineration facilities had been constructed mainly in large cities, with grants-in-aid from the Government.

As the result, by the end of 1971 in seven largest cities, 40.5 (wt) % of the total refuse went to the incinerator, and the rest to landfilling, with a trace percentage for composting. Figure 1 shows the percentage of incineration, in Tokyo, Yokohama, Nagoya, Kyoto, Osaka, Kobe and Kita-Kyushu, which all together collected the refuse of an amount of 9 million tons in 1971. This amount of waste is approximately one quarter of the total municipal refuse that was collected in Japan in the year.

With this enhancement of incineration for disposal, relatively newer incinerators have some kind of heat recovery facilities. Among them, waste heat boiler is most common for providing hot water or low quality steam to the nearby utilities or public buildings like nursing homes. Some boilers are capable to generate electricity of few thousand kilowatts, which usually is only for in-plant power use for conserving the normal utilities. Table 6 illustrates these examples practised or planned in the Tokyo and

FIGURE 1 ULTIMATE DISPOSAL OF WASTE IN SEVEN LARGEST CITIES

- FY 1971 -



Source: Large City Statistics Assoc. (Ed.): "Comparable Statistical Tables of Large Cities - FY 1971 -". (1973)

TABLE 6 ENERGY RECOVERY AT TOKYO AND SUBURBAN INCINERATORS

Plant location	Capacity (Refuse tons/day)	Generator Capacity (KW)	Electricity Supply (KW)	Hot Water Supply to	Completion
(Tokyo)					
Setagaya	900	2,500	In-plant Power	Nursing Home	March, 1969
Shakujii	600	1,500	"	-	March, 1969
Chitose	600	1,700	"	Civic Center	January, 1971
Ohi	1,200	2,500	"	Youth Center	September, 197
Tamagawa	600	2,000	"	Swimming Pool (Civic Center)	October, 1973
Koutou	1,800	3,000	"	Nursing Home	February, 1974
Itabashi	1,200	3,200	"	Ward's Public Facility	June, 1974
Katsushika	1,200	12,000	5,000 (Planned)	nd	March, 1977
Adachi	1,000	nd	In-plant Power	nd	March, 1977
(Kawasaki)					
Minkou	600	1,300	"	-	April, 1971
Tachibana	600	2,000	"	Nursing Home	December, 1974
(Yokohama)					
Kouran	900	3,000	"	Nursing Home Swimming Pool	March, 1974
Minami-Totsuka	1,500	4,500	"	"	March, 1976
(Chita)					
Shinkou	450	1,200	"	nd	March, 1974
(Reference)					
Nishiyodo, Osaka	400	5,400	In-plant Power 700 Contract Sale 2,500	-	June, 1965

nd: not determined

Suburban cities.

Since Japan is located in the temperate climate region, except Hokkaido, district heating is not practiced as in Europe and/or in a part of America. This in turn means that the waste heat recovery by incineration for district heating purpose is not practical without any piping facilities. For the electrical power generation, out-plant supply is, in principle, quite possible, although it is not performed because of non-technological reasons. Current boilers are mostly of waste heat type and the waterwall furnaces are not used extensively. Major non-technological barrier for electricity is that most electric utility companies are reluctant for this idea, simply because of low quality electricity with fluctuations both in time and quantity. In addition, most coal burning power plants had been long before modified to oil or gas-fired furnaces, in Japan.

In this respect, the only exception is the Nishiyodo Incineration Plant of the Osaka City. The plant has a processing capacity of 400 tons of refuge per day, and is equipped with two 2,700 KW generators, with output voltage of 6,600 V. Normal power output is 1,600 KW each generator. Of this 3,200 KW, 700 KW is consumed for in-plant use, the remainder 2,500 KW is for selling. Kansai Electric is purchasing this electricity with an average price of 2.46 yens per kilowatt-hour or ca. 8.2 mils/KWH (Incidentally, current end-use average price of electricity in Japan is somewhere around 7 yens/KWH, or 23 mils/KWH.)

In Tokyo, Katsushika Incineration Plant which is now under construction and shall be operated from March, 1977, will generate electricity of 12,000 KW, with a refuge amount of 1,200 tons/day. Of this, 5,000 KW is agreed with Tokyo Electric to be bought. This trend for energy recovery by selling electricity is expected to be fostered in the future with the initiative taken by the municipality sector.

For the past few years, community (civic) groups in co-operation with city's sanitation authority have been increasingly engaged in active recycling movement, in many cities. Of these, the best known one is the recycling in Toshima Special Ward of Tokyo, which often is referred to as "the Toshima Project". The principal idea for this Project is as follows: Block community societies, which have long been in existence traditionally in Japan known as "cho-kais", or communal organs, take the initiative of the Project. A participating cho-kai asks its member families to bring whatever recyclable things to a nearby specified lot on a specific data by a certain time. And the cho-kai previously had asked via its Ward's Sanitation Office to send truck(s) of recycling firm(s) to the lot to pick the materials up. The Ward Sanitation Office which belongs to the Tokyo Metropolitan Government, normally gives the permits for this activity, arranges the hauling schedule for the secondly material dealers and refunds the profit to the cho-kai.

Recently a variation of this scheme is seen: Instead of the dealer's truck pick-up, the Ward's sanitation collection trucks haul all materials gathered and transport to the dealer's plant. This variation has an advantage that the lot is kept always clean without any left-over, which is often seen in the Toshima Project.

The results by this recycling activities are summarized in Table 7.

Trends Observed in (Central) Government's Efforts

Various efforts of the Central Government through its Agencies and Ministries, have been placed for resource recovery. Among those, the Ministry of International Trade and Industry (MITI), which

TABLE 7 WASTE RECYCLING MOVEMENT IN METROPOLITAN TOKYO

FY	Participation		Recycled Materials								Revenue	Averaged each ho...	
	Groups	Household	Papers (Kg)	Rags (Kg)	Metals (Kg)	Rubbers (Kg)	Class (Kg)	Others (Kg)	Bottles	Total (Kg)	(yens)	Quantity (Kg)	
1969	3,604	1,562,272	4,191,881	210,623	494,542	16,289	575,520	388,669	125,532	5,877,526	23,786,195	3.8	1
1970	3,683	1,399,941	3,990,499	210,536	416,326	14,051	453,450	363,545	83,290	5,448,407	24,072,398	3.9	1
1971	2,771	931,319	3,427,261	194,131	327,208	9,826	599,398	422,654	51,411	4,980,478	14,388,231	5.3	1
1972	2,979	978,564	4,333,455	258,959	418,646	12,927	848,994	422,388	38,565	6,302,005	23,637,196	6.4	2

Note: Total amount does not include the number of bottles.

has been playing a supervisory role for all production industry, have been mainly concerned with recovery and reuse of industrial wastes to increase production efficiency.

However, for the municipal refuse, little attention had been paid for resource recovery till two to three years ago, except that some investigations on the state-of-the-art were performed. The Agency of Science & Technology, an independent governmental agency, through its Resources Investigation Office, was the earliest to perform this kind of surveys and studies on both the general waste and industrial waste since 1965 or 1967.

The Agency of Industrial Science & Technology (AIST) of the MITI, as shall be described later, planned a R & D Project for Resource Recovery from the municipal waste back in 1971 and one year study program budget was appropriated for the FY 1972. The R & D for resource recovery technology and system formally started from FY 1973, as one of the National Projects conducted at the AIST.

The Ministry of Health and Welfare, which is traditionally concerned with solid wastes from disposal viewpoint, has not been much involved with resource recovery until very recently.

It is generally well known that an inter-institutional project for utility-oriented resource recovery on a gigantic raft afloat or held in the coastal ocean is in its planning stage. The program had been studied by the Research Institute for Ocean Economics, a non-profit organization, for two years and the program concept was employed as a governmental project since the beginning of FY 1974. (April 1, 1974). An amount of approximately 50 million yens (ca. 170,000 US dollars) was appropriated for this study. And the participating agencies include the Environment Agency, the MITI through its Office of Ocean Development, Ministry of Health & Welfare and the Ministry of Transportation. The feasibility of

of this marine utility plant is considered very high, because this type of resource recovery plant is normally for large cities and most large cities in Japan are located on the coastal region. If, for example, such marine plant is planned in the Tokyo Bay, the plant could serve not only Tokyo Metropolis but also its surrounding suburbs in an organized manner.

At present, the plant facilities shall include (mostly) technologies and processes developed by the AIST, and the transportation of refuge from the coast to the floating plant shall be conducted by the pipeline. The plant is planned to have a pyrolysis process, desalination process and possibly materials recovery section.

Current central Government's efforts for resource recovery from the municipal waste, described above briefly, involve a wide variety of agencies. There is a trend observed, however, that those scattered efforts will be incorporated to enhance its efficiency. This means an intensive inter-institutional co-operation which is normally hindered by the "unseen" barriers. Nevertheless, it is predicted that the Environment Agency, created back in 1971, shall play an important role as the leading agency in this organization of the efforts.

Trends in Industry

Industry as a private firm or group has been traditionally concerned with recycling of only industrial wastes. This is known as the in-plant recycling. In this respect, pyrolytic liquefaction of by-products or waste plastics at the polymer manufacturing plant, for example, has been done for the resource conservation purpose. The Government (MITI) has taken an incentive policy, encouraging the industry to this kind of plant by means of grants-in-aid, low interest loans, special amortization plan of the

facilities, and tax exempts.

The in-plant recycling (known in Japan often as "closedization" of the plant) has been increasingly enhanced recently because of the decreasing number of contractors who take care of plants wastes for disposal or reuse and its increase in disposal cost as the environmental restrictions are getting severer.

Industry, in its large part, has shown no interest in resource recovery from the municipal refuse, with the exception of plant manufacturers. However, as the municipality, faced with increasing amount of industrial wastes mingled with the normal waste (it is termed as the "hard-to-dispose waste" by the municipality), started denouncing the industrial circles that they should somehow assume the responsibility for this, the industry producing these materials or products responded with showing some actions. For example, manufacturers of home electric appliances, automobiles, plastic products, and packaging materials, have shown recycling plans or programs that prevent those materials from coming into the municipal waste stream and give some technological solutions.

Normal industry's approach to this problem exemplified by first establishing functional organization with concerned firms and performing various activities ranging from establishing the data base to operating some demonstration plants, which are usually supported or funded in part by the Government. The Plastic Waste Management Institute, for example, was established back in 1972 by 34 polymer manufacturing companies. The MITI has been cooperative with the Institute since its formation, providing various assistances including subsidies, information and authorization on conducting resource recovery projects. The Institute is also instrumental in providing government's grants-in-aid for plastic reutilization programs of individual efforts. It has two recycling plants running; one in Funabashi City and another in Koshigaya City, in both of which the source separation of plastic materials or products are practiced

by the municipal authorities.

Another example of industry - Government joint project was the establishment of the Waste Paper Recycling Promotion Center. The Center was erected in June, 1974. Its primary concern is the storage of waste paper for providing stable supply and thus for higher repayment of recycled paper.

Furthermore, in July, 1974, the Japan Electrical Manufacturers Association which is representative of essentially all manufacturers of electrical appliances, established with a governmental assistance, the Recycling Association from Used Electric Appliances. The latter Association is setting many plans to recover resources from municipal bulky wastes, whose large fraction is used electric appliances. The automotive industry and container manufacturing industry show interest in establishing the similar organizations that will be involved with recycling.

Responded to those movements in various industrial circles, the Bureau of Industrial Location and Environmental Protection, MITI, planned an incentive legislation for resource recovery early this summer. However, the legislation was not succeeded because of disagreement on practical details among various industrial sectors, and was temporarily postponed. Instead, the Bureau is planning establishing an organization called the Clean Japan Center in the FY 1975. The Center is intended to couple the resource recovery effort with the "Keep Japan Beautiful" movement fostered currently by the local Chambers of Commerce. In the future, the Center is expected to merge with other centers or institutions to organize its and related activities and shall have close contact with the municipality by exchanging information and holding seminars or meeting for training the municipal employees for resource recovery. The Center in FY 1975 as one of the resource recovery efforts, shall have two model plants at selected cities, where the demon-

stration of materials recovery from the bulky wastes is to be conducted.

The Japan Resources Technical Institute with its member companies of more than 100, was established back in 1966 from the permission of the Agency of Science and Technology and has been playing a pioneering role in the resource recovery field of both industrial and municipal wastes in Japan. The Institute is the oldest of this kind and represented by various industries. Recently, as of September 9, 1974, the Institute and the National Center for Resource Recovery signed an agreement on the joint cooperative program of exchanging information on resource recovery in both Japan and the United States.

[illegible]

[illegible] Resource Recovery [illegible]

Resource recovery systems may be divided into two broad [illegible] i.e., materials and energy recovery. And each has [illegible] subdivisions. These four resourece recovery [illegible] are summarized in Table 5.

Materials recovery (MRS) systems that fall into (1) Extraction [illegible] of the Table, are called usually the front end system (FES) in the terminology proposed by Abert & Gusman of the NCRR. The rest that is classified into (2) to (4) inclusive, is the backend system (BES) in the same sense.

For each subdivision numbered in the Table, many unit operations or processes are considered. Under (1) the Extraction MRS, two types of processes are identified. The first type is the process in which products or parts such as bottles, cans or live motor of the refrigerator are reclaimed and the recovered products can easily be fed back to the nearest production line without much processing. Difficulty for this process is to identify the material to be reclaimed out of the mixed waste stream and select it effectively. Hand picking is the typical means for recovery.

The Second type process for the Extraction MRS includes the reclamation of such raw materials as glass cullet, pulp fibre, aluminum powder and so forth. The basic idea is to extract the marketable raw materials out of the refuge. And the process normally consists of crushing and sorting operations. Since the value of the reclaimed materials depends largely on the purity or separation efficiency, the processing is usually done in the multi-stage and/or multi-pass fashion.

TABLE 8 RESOURCE RECOVERY SCHEME

Materials Recovery	(1)	Extraction Material Recovery (separation/refining)	FES
	(2)	Conversion Material Recovery (chemical, biological, etc.)	BES
Energy Recovery (thermal, electrical, etc.)	(3)	Storable/Transportable Energy Recovery (pyrolysis, hydrogenatim, etc.)	BES
	(4)	Direct Energy Recovery (incineration power generation, etc.)	BES

FES: Front-End-System; BES: Back-End-System

Under the (2) category, or Conversion ERS, composting, anaerobic methanation, single-cell protein synthesis, alcohol synthesis and catalytic hydrogenation to form oils, utilizing organic fraction of the waste and calcination to form building materials or ceramics of the inorganics of the refuse, are exemplified.

The first type of the energy recovery, termed here as the (3) Storable and Transportable Energy (Source) Recovery System (ERS), includes pyrolytic conversion processes to fuel gases and oils, and sometimes to chars. It may be pointed out that the processes classified into (2) and (3) share the same process principle like pyrolysis, although the products from the (2) are considered as raw materials, while the ones from the (2) as energy sources. This means that the process operating conditions usually differ. The products from the (2) & (3) are, in most instances, subject to refining process for comparable quality with the corresponding virgin materials.

Electric power generation is typical example of the (4) Direct ERS. The process systems in the (4) category are mainly concerned with the matching of energy supply/demand relationship both in quantity and timing. Most modern incinerators with power generating facilities are known to have an unexpected lower thermal efficiency simply because of "steaming off", most of the time.

Two major difficulties are identified in the resource recovery technology system: The first one is based on the fact that no formal effective technique is known so far for process synthesis, which is of vital importance when formulating a resource recovery system with known components satisfying a set of specific regional conditions. The second difficulty is normally found in designing a resource recovery process network that is functional and flexible enough to accept all possible variations in such input/output material and energy flows as below.

- Input refuse flow is constantly obtainable in the steady-state manner.
- Input variations expected both in composition and quantity can be easily absorbed.
- Output energy and materials including not only the products but also all by-products must satisfy the local (environmental) emission standards.
- Recovered output resources of energy and materials must be in some form to maximize the marketability with comparatively higher production efficiency.

Problems Identified in Resource Recovery R & D

No matter how high level and efficiency resource recovery system is intended, fundamental principles observed in the conventional soild waste management and the environmental acceptability of the system mustfirstbe satisfied. Then comes the economic principle. Table 9 summarizes the soild waste processing principles observed under the Japanese circumstances.

In view of those general process principles, the following problems have been identified in the course of R & D, purposed for the Japanese environment:

The first problem is concerned with the hazardous materials coming into the normal municipal waste. PCB and its related chemicals, explosives, mercury vapor, several heavy metals, are examples of those hazardous materials. The inclusion of those materials occurs because of uncareful and/or illegal dumping, most frequently in the district where the residential and industrial sectors are mingled. The trouble is that the material is hazardous enough for normal handling of the waste and too little in quantity to be recovered.

TABLE 3 PRINCIPLES OF DISPOSAL AND RESOURCE RECOVERY PROCESSING

	Principle	Content
1	Volume reduction	• High operational efficiency in collection, transportation, disposal and other handling.
2	Chemical Stability	• Effective in land-filling and combustion operations to air, water and land.
3	Harmlessness	• Harmless and innocuous to man and other organisms during the course from generation to ultimate disposal.
4	Environmental Acceptability	• Minimum secondary pollutions of the processing facility. • Lesser impacts on the existing socio-economical and environmental systems.
5	Higher Economics	• Lower net processing cost with revenues from the recycled products. • Higher marketability of the recycled products.

The second problem is based on the general characteristics of the Japanese refuse; higher water and food waste content. In addition to those characteristics, the temperate climate has made it difficult to design a system which has a reasonable process efficiency and is satisfactory for the hygienic conditions.

The third problem may be somehow related to the first. In many municipalities of this country, bulky wastes and the hard-to-process refuse whose content may vary from one municipality to another, are collected separately and with different frequency at the source. And no suitable technology for those types of waste is available for disposal and/or resource recovery processing. For example, a source separation of plastic-rich products and the non-combustibles in one container is conducted currently in the Tokyo Metropolitan Areas, because of the adverse effects on the incineration facilities. No workable technology aimed at disposal or resource recovery to pick up PVC materials selectively out of this mixture has ⟷ yet been developed.

NON-TECHNOLOGICAL PROBLEMS

It may be said that, for higher levels of recycling than "the ragman recycling", no general concensus on the methodology for the implementation of resource recovery systems has yet been observed in this country, although increasing awareness for resource recovery is confirmed. This means that the non-technological factors, i.e. societal, economical and institutional factors, are yet to become mature before the resource recovery is to be implemented effectively in Japan.

The real problem appears to be the lack of proper information on resource recovery: Dissemination of technical information and administrative policies, training and education have been generally conducted not in a satisfactory manner. An expert technologist in this field and a friend of one of the authors, for example, once told that a mayor of a town with population of about 50,000 came to him to say, "My citizens are all for resource recovery. I consider the power generation is most promising. Introduce me the professionals, please". However, no one could blame the mayor.

Similar examples based on the ignorance may be cited of the consumer. Consumers, who are well aware of the need for resource recovery and often very anxious for it, buy the products that are not favorable for recycling simply because of the lacking of the proper education.

Economic Factors

Recovered resources compared with the virgin materials are generally lower graded in the quality. The reasons for this area, partly because the raw material of resource recovery, i.e., the

minicipal refuse, is far poorer material, and because of the economical disadvantage in refining or upgrading in order to compete with the virgin materials.

For some instances, the disadvantage of this kind may become no problem at all: Recycled pulp per se, for instance, is usually lower in grade compared with the virgin pulp. It has, nevertheless, its own proper usage and, in addition, can be mixed with virgin pulp for any fraction.

However, recovered plastic pellets, for example, are usually lower graded because of contamination of pigments and plasticizers, and thus have a narrower range of re-application. In this connection, it is hoped that another different system of industrial material standards for the recycled be established along with the existing standards. The latter, known in Japan as the JIS (Japan Industrial Standards), appears to be better-suited for the virgin material and its products. (Incidentally, the JIS has been handled traditionally at the AIST, to which both authors belong.)

Current Government's incentives are concerned primarily with the development of technological processes for resource recovery or disposal, and not for the recovered (secondary) materials. One of the reasons is that the recycled materials are yet to be produced on any large scale whose economical assessment is possible.

Recent awareness among the Governmental communities that the market opportunities, as far as the secondary material is manufactured on a smaller scale in a scattered manner, will be very lower and the price will be unstable, has made possible to employ a central storage policy for certain materials like paper-stock. The action taken by the Government (the MITI), in this connection, was the foundation and funding of Waste Paper Recycling Promotion Cen

in June, 1974, which was mentioned earlier in this paper. It is predicted that, in the near future, similar facilities or centers for plastics, ferrous and non-ferrous metals, will be established with the Government incentives.

The MITI is, at present, considering some form of subsidy for filling the price gap between the virgin and secondary materials, in its plan (at the Bureau of Industrial Location and Environmental Protection). Nevertheless, this and the similar plan like depletion allowances, have not yet been materialized.

Other economic incentives to change the Consumers' behaviors to favor the recycled materials or products are also discussed at different administrative levels. One way of doing this is to give an economic disincentive to tax those materials or products that have special difficulty in recycling. But again this has not yet done in any way.

Social Factors

There are many social factors involved that hinder the way to effective resource recovery. We have to admit, in our efforts of this aspect of problems, that we are behind the United States. The reason for this is mainly because of the greater social inertia for the existing system in this country. Another is due to the fact that the Japanese have a special psychological reluctance to utilize the things once used by others. These psychological and social barriers to resource recovery can only be lessened by constant education or enlightenment.

From the municipality's side, the lack of employees' education and training for resource recovery implementation is identified to be the major problem.

Another is the institutional problem. This includes not only local governments but also the Central Government, and is considered more serious than generally thought. Priority setting and consistent policy planning among the public sector is naturally of vital importance for effective and efficient realization of resource recovery.

Finally, legislative reorganization of both existing and future laws, acts, codes or ordinances for resource recovery must be cited here with a special emphasis. Current status of this aspect of resource recovery effort in Japan can be said hard to bear.

II. THE AIST'S R & D PROJECT ON RESOURCE RECOVERY

OUTLINE OF THE PROJECT

The project was initiated to provide a technological solution to the municipal solid waste problem which has various social, economical and technological impacts. The primary aim was to recover resources from the refuse. Current Waste Disposal and Public Cleansing Law states, in the Section 3 of Article 4, that the Government shall promote the development of processing technology and provide technical as well as financial aids to the local autonomous public agency. With this legal justification, the Agency of Industrial Science & Technology, MITI, in the FY 1972, conducted a year-long state-of-the art survey on the resource recovery from the minicipal refuse and studied the possibility to start a national R & D project on the subject from the FY 1973. The project entitled "R & D on Resource Recovery and Reuse Technological System", was then formally launched as the Phase I that will last for three years. (Initial budget appropriation plan was 1.6 billion yens or ca. 5.3 million U.S. dollars, for this period.)

Unlike the conventional production technology R & D projects, the emphasis was placed on the technology "system", not on any specific technology alone.

Resource recovery, needless to say, can only become realistic when it satisfies the environmental requirements. In this respect, the AIST's project, from the beginning, needed to have a close contact and cooperation with the local government bodies and the Ministry of Health & Welfare who had been traditionally in charge of solid waste management.

The aims of the project may be summarized as follows:

(1) To recycle the values at the optimal conditions
→ Resources Conservation

FIGURE 2 SUMMARY OF R & D PROJECT CONCEPT ON RECOURCE RECOVERY SYSTEMS

Goals:

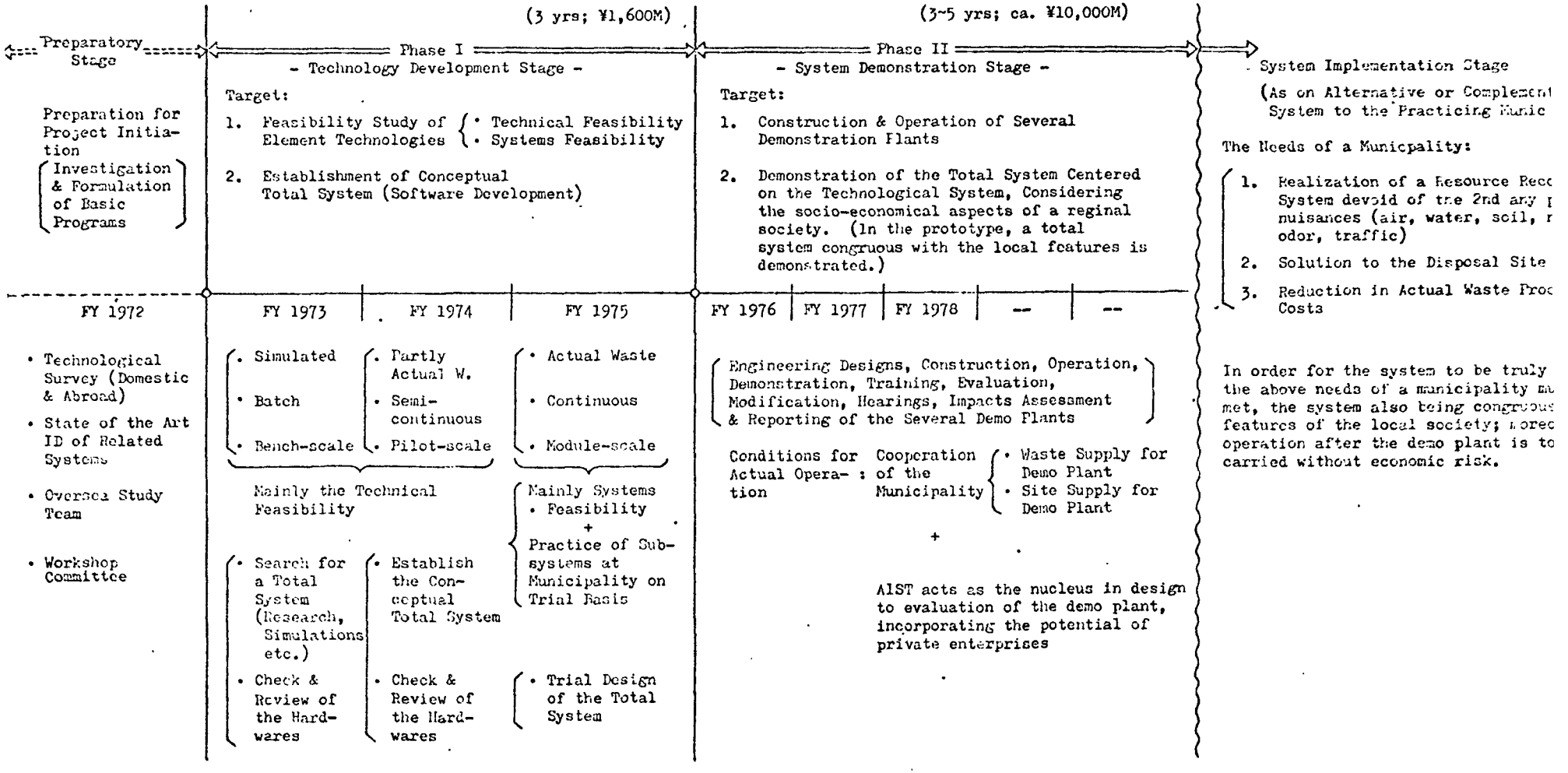
1. Conservation of Energy & Materials
2. Reduction in Net Processing Cost
3. Better Environmental Technology System

⟹ Proposal of a Prototype Refuse Processing Alternative System and its Demonstration

Application:

Unlike other industrial single-purposed technology system, the potential user of the current system for the near future at least is the local government or municipality.

Outline of R & D Programs:



Office of Research & Development Programs
Agency of Industrial Science & Technology, MITI.

(2) To establish the resource recovery technology system → Feasibility study of Elemental Technologies

(3) To establish a total system for resource recovery → Conceptual Systems Design and Incentives

(4) To propose a solution to environmental problems associated with the municipal waste → Impacts Assessment and Pollution Control

The project plan, in its first phase (Phase I), thus includes the feasibility study of selected elemental technologies and the conceptual design of a total system. The Phase II, based on the results of Phase I, proposes a demonstration of the total system with particular emphasis on the technological aspect.

The basic project concept and plan are summarized in Figure 2.

R & D PROGRAMS

Selection of the Program Fields

Elemental Technology - In a resource recovery system, the subsystems may be identified as the basic processes that should be termed here as elemental technologies. The concept of an elemental technology is somewhat similar to that of a unit operation or unit process in the chemical industry. Elemental technologies, in the development stage, may be divided broadly into two categories; peripheral or interfacial elemental technology and critical elemental technology.

The former is the elemental technology like the magnetic separator or the mechanical composting technology, that has been already applied to the resource recovery of the municipal refuse, proved to be an established technology, and has no further need for R & D. The facility or equipment of this type of elemental technology is already on the market and can be procured with specifications.

The critical elemental technology, on the other hand, is an important technology and considered critical in the R & D. One kind under this elemental technology is the technology based on totally new concept or principle. Another kind under this category is the technology, such as pyrolysis, that has been practiced in other fields of technology but has not been applied to resource recovery. And this newer application to resource recovery may require the feasibility study.

The present R & D is thus mainly concerned with the critical elemental technology.

TABLE 10 R & D PROGRAMS AND SYSTEMS STUDY OF THE AIST - FY 1973 & 74 -

Study Field	Performed at the AIST's National Laboratory	Conducted at Contracted Private Corporation
Collection & Transportation	• Slurried Waste Pipeline Transportation Technology (NRIPR)	———
Shredding	———	• Low Temperature Shredding and Separation of Plastic Wastes (Hitachi, Ltd.) • Cryogenic Shredding Technology of Bulky Wastes (Kurimoto Iron Works, Ltd.)
Sorting and Classification	———	• Air Classification and Related Sorting Systems (Mitsubishi Heavy Industries, Ltd.) • Semi-wet Shredding and Sorting Process (Ebara Manufacturing Co., Ltd.) • Magnetic Fluid Sorting Technology for Nonferrous Me (Hitachi, Ltd.)
Chemical Decomposition	• Hydrogenation and Catalytic Pyrolysis Technology (GIDL, Hokkaido) • Fixed-bed Pyrolysis Technology of Cubitted Waste for Fuel Gases (NRIPR) • Combined Reactor Pyrolysis System (NCLI)	• Fluidized-bed Pyrolysis Process for Oil Recovery (Hitachi, Ltd.) • Combined Fluidized-bed Pyrolysis/Combustion Reactor System for Fuel Gas Recovery (Ebara Manufacturing Co Ltd.)
Reuse	• Incinerator Residues Utilization Technology (NCLI)	———
Systems	———	• Conceptual Design of a Total System for Resource Recovery and Reuse (Japan Industrial Technology Association)

NRIPR : National Research Institute for Pollution and Resources, Kawaguchi
GIDL, H: Government Industrial Development Laboratory, Sapporo, Hokkaido
NCLI : National Chemical Laboratory for Industry, Tokyo

Within a process network for resource recovery, various fields of elemental technologies may be identified along the stream of the waste from its source to the ultimate disposal point. For the present R & D program purpose, four elemental technology fields were identified; (1) collection/transportation, (2) size reduction/extraction, (3) decomposition, and (4) re-utilization.

Prior to the project initiation, critical technologies for each program field were first listed and a dozen of program topics for R & D were selected. They are listed in Table 10.

One kind of slected programs, which needed rather basic research, however were assigned to be conducted at the National Research Laboratories under AIST, and the other that needed more advanced technological development were contracted with private firms that had the potential to carry out the R & D in this field of technology.

Systems Studies - Because of the complexity of the resource recovery problems, the importance of a systems approach was emphasized during the preparation stage of the project in the FY 1972.

Comprehensive study and assessment on the state-of-the art, and the subsequent systems analysis and, hopefully, a proposal of the total system with emphasis of technology, were identified to be necessary, along with the other "hardware" study programs. A systems study under the title of "Conceptual Design of a Total System for Resource Recovery and Reuse", that is listed in Table 10, was contracted with the Japan Industrial Technology Association, a quasi-governmental agency.

The JITA, being aware of the need for the interdisciplinary (and, perhaps, multi-disciplinary) study for this project, had

formed, within it, an organization called "Committee on the Systems Study of Resource Recovery and Reuse". The Committee, chaired by Prof. Dr. Yoshitoshi Oyama, currently director of the National Research Institute of Environmental Sciences, of the Environment Agency, and the former President of the Tokyo Institute of Technology, is composed of professionals with various disciplines ranging from engineering to social psychology. The Committee also had at first six and has now three workshops under it.

The first subcommittee, or Workshop on Elemental Technology is primarily concerned with the technological state-of-the-art in resource recovery. It reviews the existing and potential technologies and makes some evaluations on those technologies. One function of the Workshop is to check and review the progress status of the selected R & D programs conducted by the AIST.

The Workshop on Systems Analysis, which is the second subcommittee, is concerned with computer analysis of some problems identified critical to the project progress and making the necessary predictions. In the FY 1973, the Systems Dynamics technique, that was first developed at the Massachusetts Institute of Technology and was written in Dynamo Statements of a computer language, was utilized to analyze and predict the role of PVC (polyvinylcholoride polymer) mixed with the Japanese municipal waste.

The third subcommittee, Workshop on Demonstration Project, aims at preparing and making assessments on the coming Phase II of the AIST Project, which is to start from the FY 1976. The Phase II of the Project, described briefly in Figure 2, is essentially a demonstration of the total resource recovery system at selected municipalities, and can be comparable with the U.S. counterparts of EPA. Currently, members of the workshop are studying the social, economical and other characteristics of candidate municipalities.

Brief Review of Elemental Technology Fields

Although the goal of the project is to establish the resource recovery system, a brief review for each elemental technology field may be appropriate here. However, before we proceed to the reviewing, the total processing system that we have in our plan in its generalized form can be depicted in contrast with the existing disposal systems, as in Figure 3. The resource recovery system which is intended here is conceptual alternative of the next generation that would be a substitute for the conventional incinerators or sanitary landfilling.

Collection/Transportation:* Elemental technologies in this part of the whole processing are not directly related to resource recovery itself. However, current importance of this technology field and the relation to the subsequent processing may need a brief description.

Other than the conventional (packer) truck method, rails, ships and pipelines are under consideration for application of refuse collection and transportation in Japan. Among those, the pipeline collection and transportation is considered most promising. The pipeline has many variations; vacuum, capsule, train, pressure and slurry.

The facilities of pipeline transportation are usually costly and not economical for less densely populated areas. But once installed, the operation requires less man-power and can easily automated, which is considered a great deal of advantages over the conventional truck collection and transportation.

Most technologies regarding the pipeline collection and transportation have already developed on a commercial scale,

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* Collection and transportation may be dealt with separately. But, because of its close relation between them, no attempt was made here to separate them.

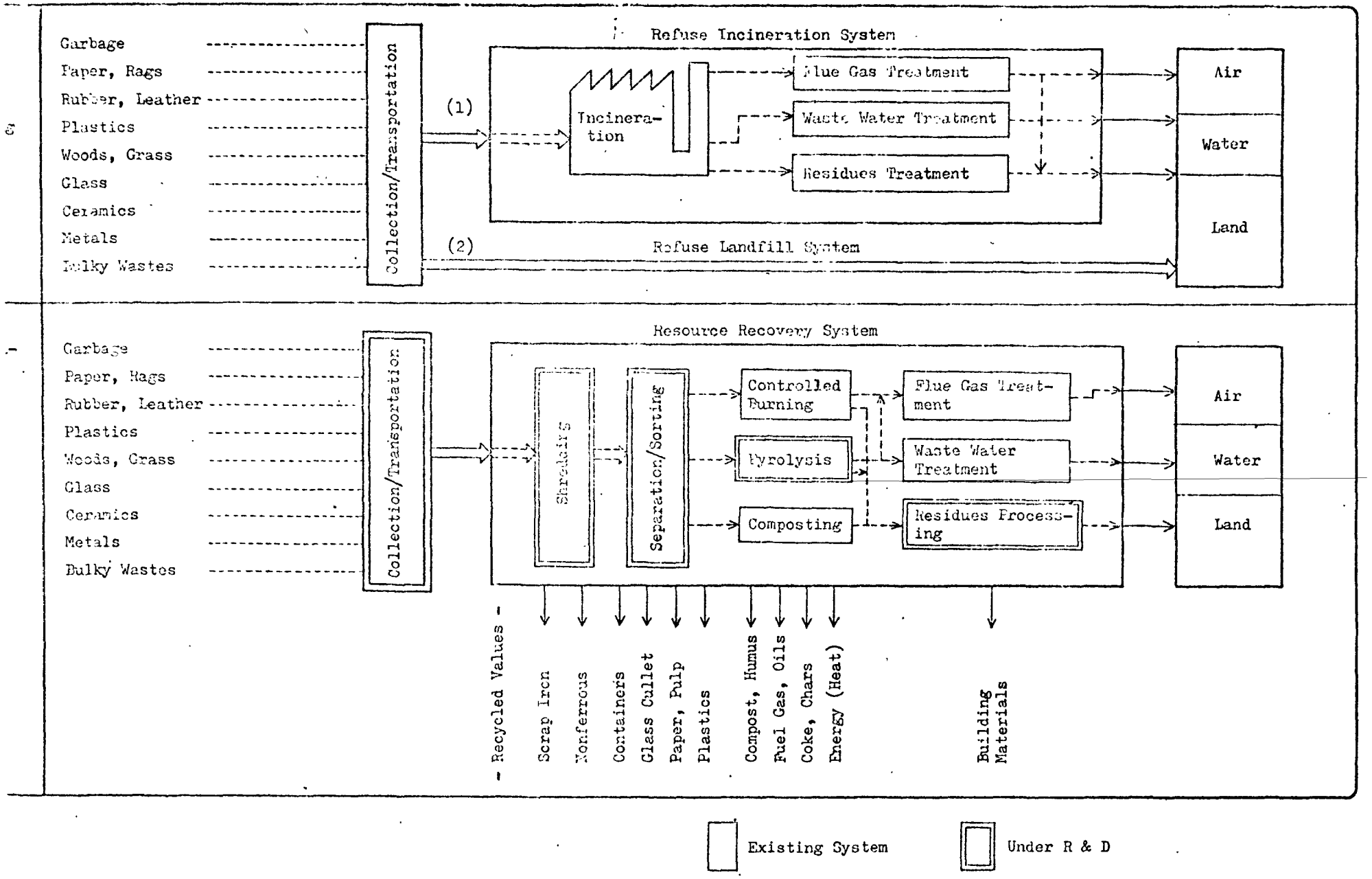

FIGURE 3 EXISTING DISPOSAL METHODS AND COMPATIBLE RESOURCE RECOVERY SYSTEM

and it appears to be not necessary to initiate new R & D programs except that of slurry pipeline transferring.

Slurry transportation of the waste or other materials like coal may be very important, particularly for the wet processing that follows. Municipal waste slurry, because of the largest content of paper, behaves, in the pipe, in somewhat similar way as the cellulosic slurry. The waste slurry contaminated with dirts, and other inorganics, is a complex Non-Newtonian fluid and its flow characteristics are not known well. The basic engineering data for designing such pipeline transportation is considered to be of extreme importance.

Size Reduction/Extraction: For size reduction, shredding is most commonly employed for the municipal refuse handling, in which combination of shearing, compression, and impact forces are utilized effectively. Hence the shredding technology is considered to be a peripheral elemental technology and not for any further R & D. However, shredders that operate at the room temperature have such environmentally adverse effects like noises, vibrations and dust, and are often not acceptable for its aesthetical and hygienic reasons. In addition to those demerits, shredders require normally greater power consumption and rather frequent maintenance job and the shreds coming from this type of equipment are not suitable for effective materials extraction operations normally that follow for resource recovery, because of their size distribution and lumping.

Cryogenic shredding, in contrast with the ordinary temperature shredding, is becoming known to compensate some of the latter's disadvantages. The basic principle of cryogenic shredding is as follows: Any solid material when exposed under the cryogenic (low temperature) conditions shows a marked embrittleness for a certain temperature range. This physical property may be utilized

effectively for size reduction and the subsequent selective extraction of certain material(s).

Various coolants may be possible for waste processing. For both economical and safety reasons, liquid nitrogen (b.p. = -195.8°C) is most promising. Liquid nitrogen is normally produced as a by-product for oxygen production from air and is totally inert gas. The latent heat (of vaporization) of imported LNG are often suggested for another source of cooling energy; nevertheless, direct utilization of this (cooling) heat seems impossible because of LNG plant location and its need for special handling.

Firsthand estimates favor the application of cryogenic shredding to the resource recovery processing, because most adverse environmental effects accompanied by the ordinary temperature shredding would be removed. However, this newer technology application needs further research and development. Economical disadvantage of using considerable amount of liquid nitrogen (the normal liq.N_2/refuse ratio ranges from 0.3 to nearly 1, on the weight basis) may or may not be compensated with many advantages.

Technologies associated with materials extraction, in general, are based on a wide variety of principles: gravity (or density), air or hydro-dynamics, particle size or shape (screening), electrical conductivity, magneticity, electrostatic force, optical property, and so on.

Thus the selection of critical technologies for R & D purpose is usually very difficult. For the AIST programs, importance was placed on that the technology as a component of a total processing system should perform most effectively with respect to upstream size reduction and downstream backend components of technology. And the feasibility for the Japanese waste was emphasized, too.

Air classification technology was selected because the technology had never been properly applied to the wet Japanese refuse, though the air classifier is operated on a commercial scale abroad. Plastics extraction in rather purified forms of pellets or powder by means of organic solvent (xylene) was another example to study its applicability to the plastics-rich Japanese waste. The semi-wet selective pulverizing system, with a great success already with the completion of the first year of R & D, is considered best fitted to the Japanese waste separation.

For separation of the inorganic fraction, most of the conventional processing technologies may be applicable that have been in practice in the minerals processing. However, newer technology may be worthy to be studied also. A technology for separating various non-ferrous metals by means of magnetic fluid (Ferrofluidics, for example) is a R & D program currently underway. This can be said of a processing with a heavy medium with variable, but controllable by a dial, apparent density to separate selectively the metals, one kind at a time.

Decomposition: Solid wastes may be decomposed thermally, chemically and biologically. In view of its importance, let us restrict our discussion here to only the thermal decomposition of the organic matter. Pyrolysis, in its strict sense, is the thermal decompostion in an oxygen lacking environment. However, often known "pyrolytic" processes include partial oxidation (or combustion) and, may be not called pyrolysis strictly. Because of this, the term "thermal decompostion" is used here in a much broader sense than pyrolysis, and distinguished from the incineration or combustion in that the latter is the thermal decomposition with an excess amount of air or oxygen.

As stated earlier, the thermal decompostion is one of the most promising technologies for resource recovery, because it can

be used for conversion materials recovery as well as energy recovery in a storable and transportable form. More than a dozen processes are being proposed for this purpose both in Japan and abroad. Nevertheless, it may be agreed that none has been proved to be completely workable on a commercial scale with the products being recovered in an acceptable manner.

General conditions for success of these thermal decomposition processes are considered more stringent in Japan, simply because of the higher moisture content of the Japanese refuse. The organic fraction of the Japanese waste, however, is still considered essentially cellulosic with some amount of hydrocarbons from plastics.

In analyzing a thermal decompostion process of the solid organic material, two distinguished reaction stages should be clearly identified; endothermic and exothermic. In order that the solid organic matter be decomposed, heat must be supplied to increase first the enthalpy of the material to a decomposition temperature and then enable the decompostion reaction occur, which, in most instances, is endothermic. As the decomposition to lower molecular state of the matter proceeds, the second stage reaction(s) between the products and the surrounding gases will take place, which is (or are) usually exothermic. Partial oxidation, hydrogenation utilizing superheated steam, or carbon monoxide, and certain condensation reactions are such examples. First and second stage reactions could occur in a series or almost simultaneously, depending on the reaction scheme and the reaction conditions.

At any event, the reactor(s) is so designed that the selected reactions effectively and efficiently be taken place. Thus the various classifications of the thermal decompostion processes are possible:

The way of supplying the heat of the first endothermic stage

may divide the processes into, 1) external heating, 2) internal heating, and 3) partial oxidation processes. Or, according to the major final product state, another way of subdivision of the processes are, 1) gasification, 2) liquefaction, and 3) carbonization. One has to know, however, that, in either one of these processes, three phases of the final products do exist; for example, in a gasification process, a small amount of liquids and solids (chars or inorganic residue) are obtainable as by-products.

Equipmental features often become the name of the processes; 1) single, and 2) combined, or dual reactor pyrolytic systems, or 1) fluidized-bed, 2) fixed, or packed-bed, and 3) rotary kiln reactor processes. Furthermore, operational characteristics divide the equipment types to; 1) batch, 2) continuous, and, 3) semi-continuous processes.

With these diversified modes of thermal decompostion processes, one may easily imagine, by the combination of those subdivisions, how many processes could be possible. The point is, however, that a pyrolytic process must first satisfy the basic disposal and resource recovery principles cited earlier (see Table 9) and be efficiently operable, without causing any environmentally adverse effects.

For the AIST R & D programs in this elemental technology field, three fundamental researches and two more advanced, practical developments were selected. (Refer to Table 10).

Basic studies include, 1) fixed-bed gasification of molded waste, 2) catalytic and hydrogenation fluidized-bed reaction for liquid products, and 3) combined reactor system for gasification.

Fluidized-bed gasification and liquefaction are two contracted, but 100 percent supported by the AIST, selected R & D programs

in this technology field.

We believe, with these five research programs of thermal decomposition, that, by the end of the Phase I term, we will be able to tell which would be the best pyrolytic process for the Japanese solid waste under a certain set of condtions.

Reutilization: Elemental technologies under this category range from incinerator residue reutilization to wallboard manufacturing process from compost humus. They cover so wide range of technologies and can not be classified in any specific manner.

The importance of this process, however, lies in that the final product(s) should have the higher marketability. In other words, the products have already an established market value and the usual lower grade of the products from waste should not be disadvantageous in the market opportunities.

One basic research program of this project is being conducted at one of the AIST's Laboratory, which is aimed at the reutilization of incineration and pyrolysis residues. Because of relatively smaller fraction of metals contained in them, tiles, bricks and certain ceramics, along with application of chars, are the major concern.

Target of Major Selected R & D Programs

1) Low Temperature Shredding and Separation of Plastic Wastes: To separate PVC plastic fraction selectively out of the source separated plastic wastes by means of refrigeration.

2) Cryogenic Shredding Technology for Bulky Wastes: To perform an effective size reduction and separation of complex products or materials that occupy major fractions of bulky wastes and are not suitable for regular shredding.

3) Air Classification and Related Sorting System: For the first year program, to classify the humid Japanese waste effectively into the organic and inorganic fractions by means of air classificatic technology.

4) Semi-wet Shredding and Classification Process: To classify the damped or moisturized waste into easily processable fractions and separate the values, like pulp stock, with higher purity.

5) Magnetic Fluid Sorting Technology for Nonferrous Metals: To separate valuable nonferrous metals, such as aluminum, copper, zinc, etc., out of the nonmagnetic inorganic mixture of the waste.

6) Fluidized-bed Thermal Decomposition Process for Oil Recovery: To obtain oils or liquid fuel products effectively by the thermal decompostion of the organic fraction of refuse.

7) Fluidized-bed Pyrolysis/Combustion Dual Reactor System for Fuel Gas Recovery: To apply the dual ractor pyrolysis technololgy to obatin high caloric fuel gas out of the organic component of solid waste.

DEVELOPMENT STATUS OF MAJOR R & D PROGRAMS

Low Temperature Shredding and Separation of Plastic Wastes

First year work (FY 1973) includes basic study on low temperature pysical properties, like embrittleness, of plastic materials, heat transmission test of plastic wastes in the low temperature range, and the feasibility of shredding operations at lower temperatures. Those studies proved the low temperature shredding and the subsequent separtion of PVC polymers from other plastic wastes was feasible.

Second year study develops an optimal process for this purpose and provides the equipmental desin and operational specifications for the whole process including the cooling-duct and the shredders.

Construction and operations of a pilot plant with a processing capacity of 50 Kg/hr should be completed by the autumn of 1975 and the final continuous operation using the source separated plastics (in Tokyo) in order to accumulate the performance data should be followed till March 31, 1976.

Cryogenic Shredding Technology for Bulky Wastes

This R & D program shall complete within this fiscal year, i.e., by March 31, 1975. In its first year, a batchwise operated equipment was constructed to test such non-crushables as washing machine motors, steel coded tires, or the like, to recover copper, steel, hard plastics, rubbers, etc. Shredding characteristics, particle size distribution, for example, and cyogenic properties

of the constituent materials were studied and an optimal set of operational conditions was searched to minimize the amount of liquid N_2 to be consumed. Also an engineering design of a continuously operated equipment, which was patented, was completed.

At present, the continuous process equipment with 1 ton/hr capacity has been constructed and soon the data collection operations should start. Economical feasibility should be studied concurrently.

Air Classification and Related Sorting System

A 1 ton/hr (dry basis) pilot plant having three major units of horizontal, vertical zig-zag air classifiers and a vibrating screen, was designed, constructed, and operated to separate the organic and inorganic fractions effectively from the Japanese refuse. First, prepared wastes with different compositions and moisture contents, and then actual waste were used to test the process performance. With an "as-received" refuse with moisture content of 42 percent, the data showed a better than expected result for the separated organics with more than 99 percent purity, while the separated inorganic fraction was contaminated with the organics and resulted in a purity being less than expected.

Currenly in its second year program, a process for recovering plastic materials in refined form from the separated organic stream by air classification is being developed. A pilot plant, based on a bench-scale laboratory test for this solvent (xylene) refining process, was designed and is being assembled now. The test operations shall soon begin to collect the performance data.

The third and final year program includes materials extraction

from the inorganic fraction obtained from air classification. A process consisting essentially of froth floatation and heavy media separation methods is planned to recover ferrous metal, aluminum and glass. The latter half of the third year shall be devoted to organize all processes developed during the three years as a total sorting (materials recovery) system.

Semi-wet Pulverizing and Classification Process

The technology based on a totally newer concept is substanciated in a trommel-like equipment. The municipal waste with as-received moisture or damped, if necessary, is fed to one end of the rotating drum with screen holes and hammers equipped with inside and rotating at a different speed. Homogenization of the waste through the diffusion of the moisture and the size reduction by tumbling and hammering actions take place almost simultaneously as the waste move in the horizontal, longitudinal direction. During this process, selected materials as being pulverized will be screened out and classified automatically. Three stagewise classification of the refuse has been proved most practical with an acceptable efficiency.

Tests done by a model and module units (both operated batchwise) in the first year research evidenced that one of the classified refuse was essentially all high quality recyclable waste paper. And a waste paper processor recovered paper sheets from this fraction on a trial basis, and guaranteed the quality of the recovered material. This is probably the simplest process to separate the paper (recyclable alone for better sake) from the mixed refuse without any known environmentally disadvantages. (No air, water and possibly soil pollutions are expected, in addition to the less power consumption than the conventional processes.)

This year is devoted mainly to modification of the test module equipment to a larger model unit to check the scale-up factor. And the designing of 2 tons/hr single drum continuous equipment is being done concurrently so the equipment will be assembled by the end of this fiscal year.

In the next year, a demonstration plant of this process will be constructed at a landfilling site of a suburban city of Tokyo. and further performance data will be accumulated before commercialization.

Magnetic Fluid Sorting Technology for Non-ferrous Metals

The magnetic fluid, which consists of magnetite (Fe_3O_4) particles of ca. 100 Å average diameter coated with a surface-active reagent and suspended in a base medium, usually water or kerosene, plays a central role in this separation technology. The fluid once placed in a magnetic field, possesses an apparent density corresponding to the field force. A particle of any non-ferrous metal submerged in this fluid, therefore, may either float or sink, depending on its specific gravity. And this is the principle of this technology.

A batchwise equipment was built in the first year program and the some basic research was conducted for the feasibility of the process for the waste. The process input must be an inorganic residue after the ferrous metals extracted completely by a magnetic separator and a mixture of non-ferrous metals and glass, ceramics or the like. The first year study concluded that both floating and sinking units were necessary for effective separation of aluminum and copper. And also some means to recover the valuable fluid that would be carried over along with the separated metals must be

developed. Otherwise economics of the process using the very expensive magnetic medium* seems not realistic.

The second year program includes the development of a continuous process equipment with capacity of 100 Kg/hr. And an unit of pretreatment by means of eddy current separation of non-metals and an additional medium recovery unit will be attached to the main part of the process. The performance data are to be obtainable within this year. Some make-up experimental runs may be necessary before commercialization in the next fiscal year of 1975.

Fluidized-bed Thermal Decomposition Process for Oil Recovery

First year experimental study was performed utilizing a pilot plant with reactor of 160 mm Ø. Simulated wastes with varying plastic composition[3] were used to investigate the yield of liquid fuel product. Also process heat balance was studied in order to determine the way to supply heat to decomposition reaction in the fluidized-bed reactor. The result seemed favorable for the partial oxidation taking place in the reactor for oil recovery without much changing the heating value of the liquid product.

The first few months of the second year (FY 1974) is being devoted to investigating the process performance with an actual

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* Current price per liter of this liquid for research use is ca. 100,000 yens, or 350 U.S. dollars. We expect the price will drop to 1,000 yens, or 3 dollars per liter by the time of commercialization.

waste. A scale-up reactor with diameter of 500 mm ϕ is in its designing stage and soon will be constructed. In the third year, nearly a commercial scale plant will be constructed and operated for the actual waste on a continuous basis.

Fluidized-bed Pyrolysis/Combustion Dual Reactor System for Fuel Gas Recovery

The basic idea of this process is as follows: The sand, fluidization medium, mixed with chars produced in the pyrolytic reactor flows to the second combustion reactor where the air is being blown from the bottom and the burning of the chars take place. The heated sand in the combustion reactor and being free of chars any more then travels back to the first pyrolytic reactor through a pipe to provide the heating and reaction energy to the shredded waste. Thus the sand, through circulating between the two reactors, acts as an energy carrier and the two reactors are normally in a thermally equilibriated state with a certain feed rate.

This dual reactor system has been employed in petroleum cracking process and not totally new. The advantages of this system are that the process is suitable for higher caloric gases and the operation can easily be automated because of its inherent stabilit

The first year study was mainly concerned on the pyrolytic reactor section. (Combustion reactor that could be combined with is in a wide spread use already.) Thus a single reactor with diameter 300 mm ϕ system was designed and the feasibility of the pyrolysis process to the Japanese waste was checked. Waste paper stock being pulverized was used to test the equipment. And a fuel gas with the lower heating value of nearly 4,000 Kcal/Nm^3 was obtained at about 830 ^{o}C. Moisture content was a testing parameter and an interesting result was obtained.

Currently, the sand circulation is tested on a model unit of the same geometry of the reactor system at the room temperature. And the design of a reactor system with 500 mm Ø for each reactor is being performed.

In the final year, a module size plant will be constructed and tested of its feasibility on the actual waste.

Conceptual Design of a Total System for Resource Recovery and Reuse

A partial description of the activities being done under this contracted study was made earlier. See Systems Studies, on pp 42-44.

Current major activity of the Systems Study Committee is about the preparation for the coming Phase II demonstaration programs that shall start from the FY 1976.

THE PHASE II [illegible]

The Need for Phase II of the Project

We are now (FY 1974) in the middle year of the three-year term of Phase I of the AIST's Resource Recovery and Reuse Project. As stated partly earlier, the objectives of Phase I are; 1) technical and system feasibility of selected elemental technologies to apply under the Japanese physical and social conditions, and 2) conceptual design of a total system for effective resource recovery systems implementations. At the end of the Phase I, we could not estimate, however, that all elemental technologies developed under the Project and/or the total system proposed should be implemented shortly thereafter on a "commercial"scale.

The reasons for this may be as follows: Firstly, those technologies, unlike the conventional production technologies, for lack of economical interest, should not be implemented without any economical aids or incentives of any form. Secondly, municipalities are considered still not yet being ready enough to accept the resource recovery concept in a more realistic manner. Thirdly, and most important of all, the system demonstration, which is most needed by the municipality instead of single technology demonstration would have not yet performed then.

Because of these reasons, most municipalities being still within amortization period of current disposal (mostly incineration) facilities may find the resource recovery systems implementation too risky to take both in the economical and technical terms. Therefore, we have to conclude that we need the systems demonstration for a certain period of time before municipalities would start implementing the systems safely.

Outline of Phase II Plan

Based on the need justified above, the AIST is now planning a demonstration project for the Phase II that should be directly followed by the current Phase I. The system we would pursue may include as much results of the Phase I term as possible.

The outline of the Phase II plan may be briefed as follows:

Period: Three to five years starting with FY 1976.

Total Budgetal Appropriation Planned: Approximately 10 billion yens, or 33 million U.S. dollars.

Method: Construction, operation and evaluation of several demonstration plants in selected municipalities.

Demonstration Plant: Prototype systems that match the local conditions to be demonstrated. Plant processing capacity varies according to the locality and demonstration purpose. However, generally more than 100 tons of refuse per day may be necessary to demonstrate the economical factors. Prototypes include total systems, each including the existing facilities, like incinerator, as the subsystems. Others may include systems centered on materials recovery and/or energy recovery.

For the demonstration plants, municipalities should provide the refuse and the site on which the plant construction would be made. The AIST, or the Government, on the other hand, should guaranttee plant hardwares, construction, operation and maintenance during the demonstration period.

Training of employees of ther municipalities, operations of the plant under extreme condtions of incoming refuse, assessments on market opportunities of recovered materials or energy, and on the environmental impacts, are planned with the consultation of the selected municipality.

At the end of the demonstration, had the municipality so desired, the whole plant might be acquired by the municipality based on the general disposal rules of Government properties. Or else it could ask the AIST to remove the plant.

CONCLUSIONS

From the discussions in the first half of the paper, the following concluding remarks may be summarized:

A. The old syle "ragman recycling" is currently seldom seen in Japan.

B. Increased public awareness for resource recovery from the municipal refuse has been observed especially for the last two years.

C. For processing (disposal or resource recovery)purpose, approximately 20 percent industrial waste normally coming mixed with the regular waste causes various trouble to the municipality.

D. Source separation is considerably wide spread among Japanese municipalities, mostly not for recycling but for more effective disposal processing. (Separation of plastic products because of expected damage to the incinerator, for example.)

E. The main features of the Japanese municipal refuse, compared with the U.S. refuse, are higher average moisture content (more than 50 percent) and higher fraction of plastics (reaching nearly 10 percent).

F. The Japanese paper recycle ratio is exceedingly higher than the figure of the U.S. counterpart, and anticipated to increase still further.

G. Incinerators are in a wide spread use among the Japanese municipalities. But heat recovery is not performed as much as being done in Europe.

H. Industrial and public (including the Central Government) sectors show a great deal of interest in resource recovery from the municipal refuse. And various efforts are beginning to be taken.

I. Technological problems identified here include processing of waste contaminated with hazardous materials, storing of putrescible refuse or recovered materials, and resource recovery processing of source separated materials.

J. Nontechnological problems identified here include economics of recycling processing and recycled resources, and social acceptability of the resource recovery concept and recycled resources. The solution of these problems would take much longer time than the technological ones.

Conclusions, based on the AIST's Project description in the latter half of the paper, may be as follows:

A. R & D programs are being conducted on selected "critical" elemental technologies. And the problems encountered were identified not much of technical feasibility, rather of systems feasibility.

B. One of the difficulties in the resource recovery process designing is to synthesize a processing system that absorbs the input refuse variations in compostion and quantity.

C. System design or process synthesis techniques for resource recovery systems that must satisfy the diversified local conditions has not been developed in a satisfactcry manner. The need for this kind of study should be emphasized.

D. R & D programs performed during the Phase I period alone may not be sufficient for the municipality to implement as a resource recovery system. And the Phase II of the Project may be necessary for the system demonstration before the municipality employs the system shown by the AIST without much technological as well as economical risks.

E. Currently planned Phase II includes construction, operations, maintenance and assessments of the demonstration plant of several selected cities.

The MITI, with its conservation of energy and materials policy, has been and shall promote, through the AIST, R & D programs on resource recovery systems, and, through its other Bureaus, various economical and administrative incentive programs to conserve the resources from various wastes, including industrial waste, with cooperation of civic and industrial sectors.

A. Hydrogenation and Catalytic Pyrolysis Technology

Government Industrial Development Laboratory
Hokkaido

RESEARCH CONCERNING THE TECHNOLOGICAL DEVELOPMENT OF RE-USE OF ORGANIC HIGH POLYMERS' WASTES BY CATALYTIC HYDROCRACKING

(THE PURPOSE OF THIS RESEARCH)

It is a purpose of this research to get basic data for establishment of a process to dispose organic high polymers' wastes by catalytic hydrocracking and to convert them into completely harmless and reusable substances.

(THE PROGRESS OF THIS RESEARCH UP TO THE PRESENT DATE)

Using a batch autoclave, we have being hydrocracked the organic high polymers in the presence of various catalysts and investigated the conversion and the properties of reaction products at the reaction temperatures of 250 ~ 500°C and the reaction hydrogen pressures of 20~200 Kg/cm^2.

We hydrocracked cottons, polystylene, polypropylene, phenolresin, and melamine resin under the above reaction conditions.

Polystylene could be hydrocracked to alkylbenzenes.

Polypropylene could be hydrocracked to $C_1 \sim C_4$ paraffine gases and gasoline fractions.

Phenol resins could be hydrocracked to alkylphenols.

Melamine resin could be hydrocracked to ammonia, methane, and amino methanes.

Cotton could be hydrocracked to $C_1 \sim C_4$ paraffine gases, alcohols, and aldehydes.

(NEXT STEP OF THIS INVESTIGATION)

Organic high polymers such as celluloses and plastics have a uniform and regulaly ordered moleculer stracture.

In order to utilize their wastes efficiently, it would be most desirable to convert them selectively into monomers.

Following the present work, we will try to hydrocrack typical high polymers catalitically, at the same time to investigate the hydrocracking reaction process and to get basic data for designing a disposing plant.

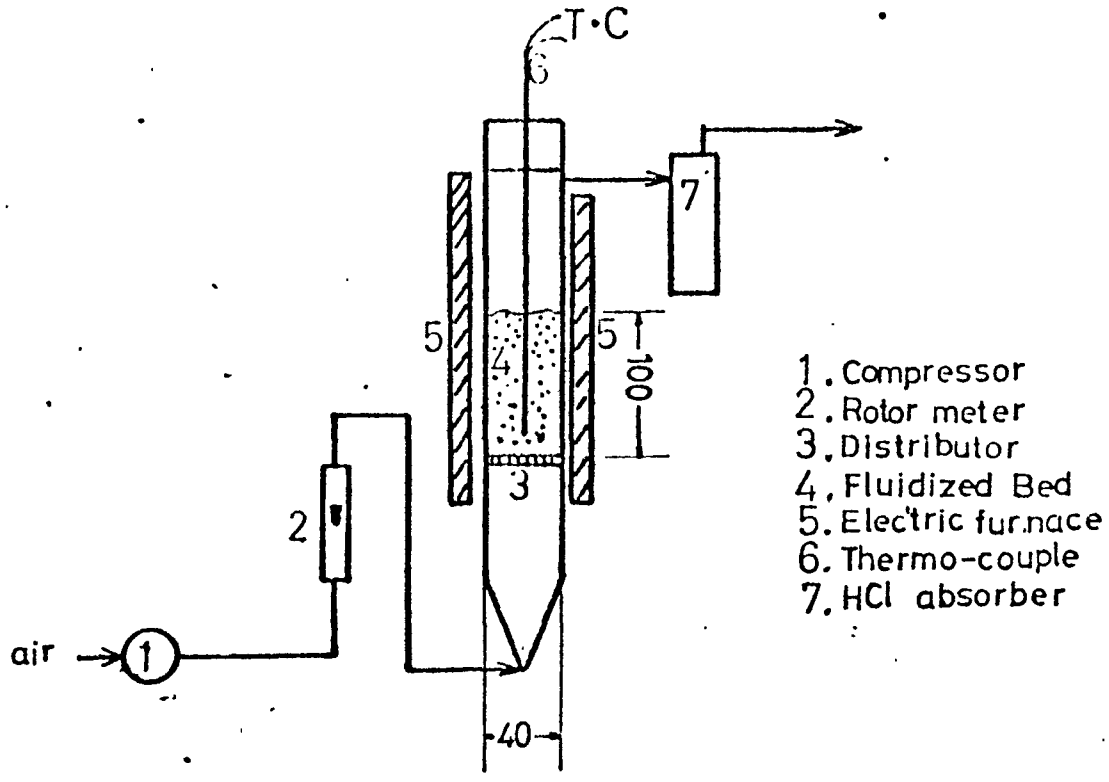


Fig.1 Batch Fluidized Bed Reactor

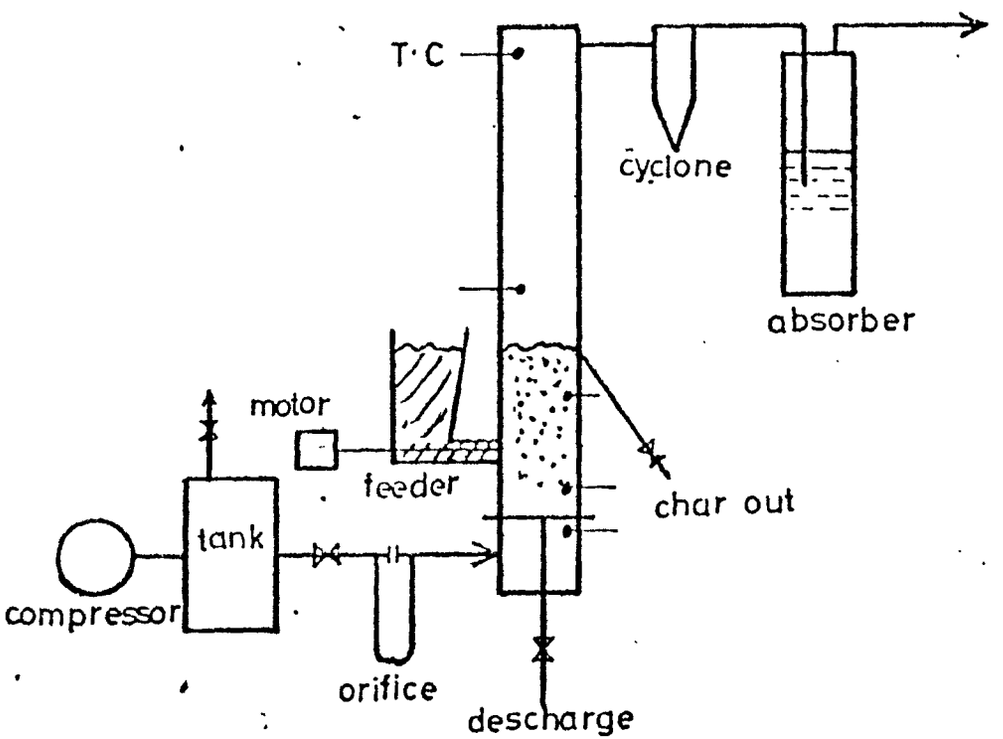


Fig.2 Contenious Fluidized Bed Reactor

Year	Hokkaido. Laboratory G.	Hitachi Ltd.
	Objects: ① Measurement for the rate of liquifaction of cellulose materials by batch fluidized bed process ② Effect of fluidized gas on the yield of liquid product. ③ Optimum temperature range. ④ Effect of air and inert gas on the yield of liquid product. ⑤ Mixture of plastics and cellulosic materials.	① Batch process was carried using SUS 32 reactor, 15 cm dia. Feed rate : 5 kg/hr. Temp. range : 400 ~ 800 °C U_0 : 5 ~ 20 cm/sec Polymer : cellulose = 1 : 1 ~ 4
48	Apparatus: ① The specification of ~~batch~~ batch type-glass fluidized bed reactor are as follows. a) diameter : 35 mm. b) medium : Sand bed. c) average dia. of Sand particle : 0.2 mm d) gas velocity : 0 ~ 5.0 cm/sec e) materials used : PS, PP, PE, paper and wood respectively, or their mixtures. f) height of bed : 0 ~ 20 cm g) temp. range : 300 ~ 550 °C h) carrying gas : air or inert nitrogen. i) The gaseous products are cooled with water and the non-condensed portion are purged.	② capacity of Autoclave : 1 liter Temp. of charge : up to 650 °C ③ The amount of charge was increased without flow rate. ④ Char yield : 15 ~ 20 wt % ⑤ Gas " : 15 ~ 25 " ⑥ Liquid " : 50 ~ 65 " ⑦ The constituents of liquid portion were mainly water, oil and Tar. (percent ratio ; water : oil : tar = 20 : 50 : 30). ⑧ The energy balance was studyed. The heat efficiency of liquifaction was better than that of gasefication.

j) gas analysis: $CO, H_2, CH_4, CO_2, N_2, O_2$ etc.

② Stainless fluidized bed reactor is designed and operated to obtain continuous data. The experimental results are as follows.

a) optimum temp.: 400~430 °C

b) The yield of liquid products is increased with the amount of

43. additional plastics used.

c) The effect of air on the amount and yield rate of oily products is better than inert gas.

d) The fixed bed favors the yield of oily products.

e) The tar obtained is unstable and polymerizable.

f) Calorific value of the liquid, gaseous products and tar are 4,000, 5,000 and 2,000 Kcal per Kg. individually.

Objects:

1. To investigate the optimum operation conditions for the continious fluidized bed reactor in 15 cm diameter

45. 2. To analysis the continuous data.

Apparatus and Operation Conditions.

(1) Temp range: room temp. ~ 350~650 °C

(2) U_0 : 0 ~ 10 cm/sec

(3) Bed height: 10 ~ 25 cm

(4) Feed rate 5 ~ 20 Kg/hr.

1. To make 50 cm dia reactor for urban refuse treatment.

2. 16 cm dia reactor is used ~~for~~ to obtain correct ~~and~~ conditions.

3. To operate long run: over 200 hrs.

4. To reate off-gas.

5. To study the utilization of the products.

H. Kishi	Hitachi
Results: (1) The capacity of reactor and the samples of medium are effected by the operation variables such as temperature and Ue. (2) The chemical Engineering problems are investigated.	6. To make bottle a feeder
Objects: 1. To measure the water contents and energy balance in the reaction system. 2. To obtain the process engineering data, e.g. for pipeline feeder, discharge and condenser etc. 3. To investigate the utilization of the liquified products and char especially. 4. To analyze the products thermally decomposed. 5. To study the reaction rate of thermo-oxidation, critical capacity of reactor, design and analysis of fluidized bed reactor.	To investigate for comarcial plants, it will be treated 10 t/day.

[illegible] Technology of Digested Waste [illegible]

National Research Institute for Pollution and Resources, Kawaguchi

Fixed Bed Pyrolysis of Municipal Organic Solid Wastes Briquett

National Research Institute for Pollution and Resources,
Kawaguchi, Saitama, Japan, 332.

This fundamental research programme deals with not only the resolving the impact of solid wastes pollution, but also resources recovery from them.

Pyrolysis using fixed bed for organic solid wastes is to be allowed easy and steady operation, which is the one well-established at many other industrial fields. Because constitutions and shapes of solid wastes vary with various conditions (time, place and so on).

The fundamental research has been focussed particularly to;

1, Possibility of briquetting of solid wastes,

2, Molding of and removing water from solid wastes by means of compression with or without addition of binding maerials,

3, Thermal decomposition behaviours of briquett as functions of temperatures and duration time. The influences of circumstances and catalysts during the decomposition are to be tested.

4, Material balance and heat balance in the course of thermal decomposition,

5, Concept design of pyrolysis oven in the basis of results obtained, and

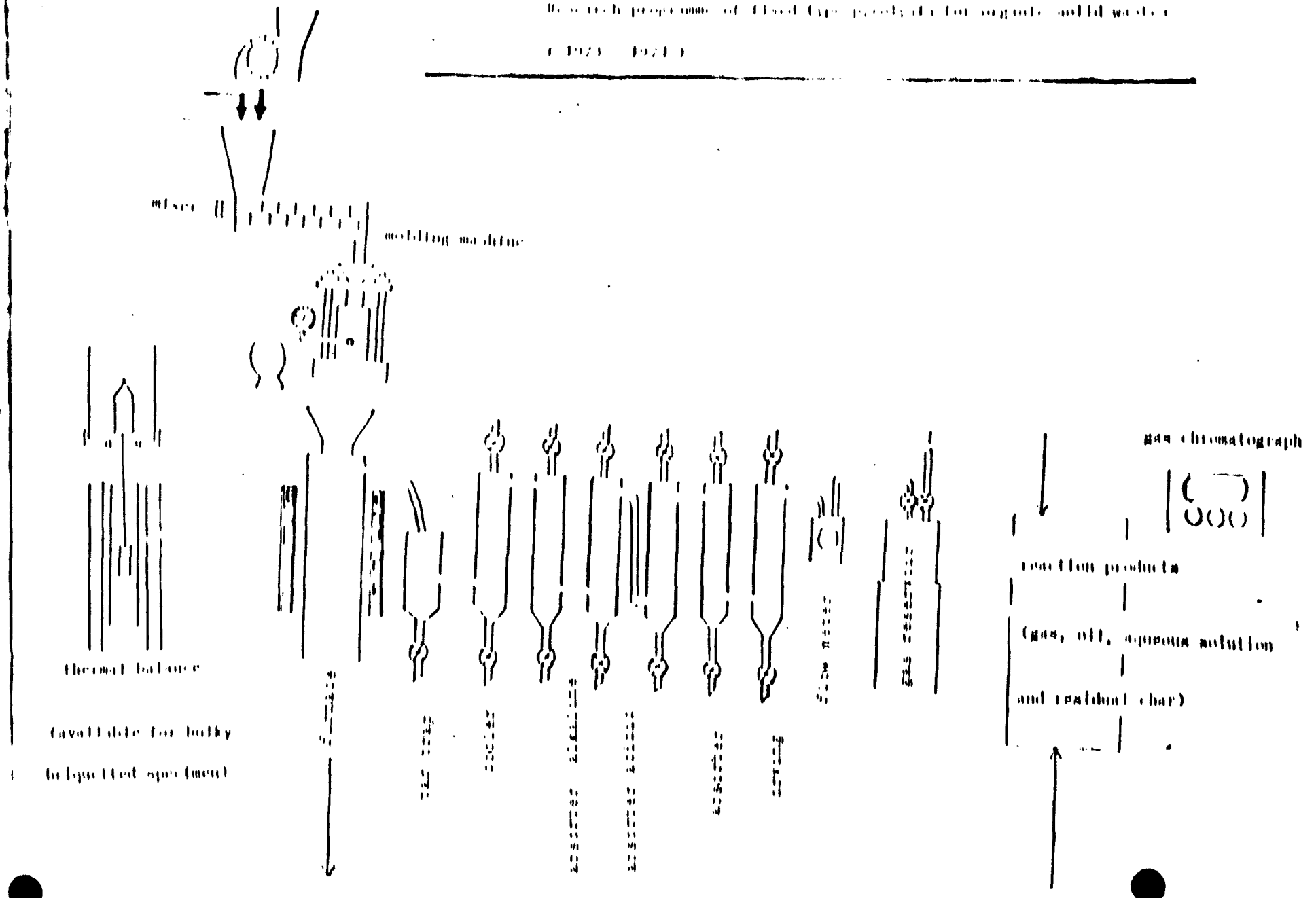
6, Analysis and use of decomposition products (gas, liquid and residual char).

Research Programme on Fixed Type Pyrolysis of Organic Solid Wastes

Fiscal year	Item of Activites
1973	The constitution of solid wastes and their thermal decomposition behaviours, Analysis of thermal decomposition products from solid wastes, Relation between briquettability and solid wastes constitution,
1974	Molding of and removing water from solid wastes by means of compression with or without addition of binding materials, Strength of briquett made of solid wastes during drying and pyrolysis, Mechanical strength and reactivity of char obtained by pyrolisis, Removing of the pollutants such as gaseous and liquid S-, N-, Cl-containing matters evolved,
1975	Design and building up of fixed bed type oven (carbonizer), Material balance and heat balance for solid wastes carbonization reaction.

Research programme of fixed type pyrolysis for organic solid wastes

(1973 - 1974)



[illegible]ined Reactor Pyrolysis System

[illegible]nal Chemical Laboratory for Industry
Tokyo

Development of the Hybrid# Retort to Gasify Urban Refuse

National Chemical Laboratory for Industry

The hybrid# retort is a gasification plant which has been invented in National Chemical Laboratiry for Industry as a unit process in the resource recovery system for urban refuse.

The hybrid# retort is characterized by the idea that the retort is not a single unit but is composed of a moving bed gasification unit and a cirtain type of incinerator so as to make the best use of the two units. The incinerator is allowed to choose any type of solid gas reactors such as a conventional grate kiln, a rotary kiln, and so on. While the gasification unit must be an up flow type of moving bed to which the solid waste is fed from the bottom and the incompletely decomposed solid is discharged from the top of the bed as shown in the figure. The retort is expected to exhibit following effects.

(1) By employing a double stages retort, the gasification unit and the incinerator are hybrided to make the process most effective with a sence of optimization.

(2) High calories gas can be produced due to sufficient contact of the solid with partial combustion gas.

(3) Blockage trouble of the solid bed can be shouted and stable operation can be continued even the solid bed itself forms a blockage, because the solid waste is fed from the bottom of the gasification unit and lifted up with a mechanical force.

(4) Since the solid waste can decompose with taking sufficient time, the solid of a large size can be treated, consequently pretreatment of the chage can be simplified.

(5) The operation is so stable over a wide range as to keep little advancement of gasification. This characteristic is quite favorable to suit operation schedule.

(6) Low construction cost and less friction damege.

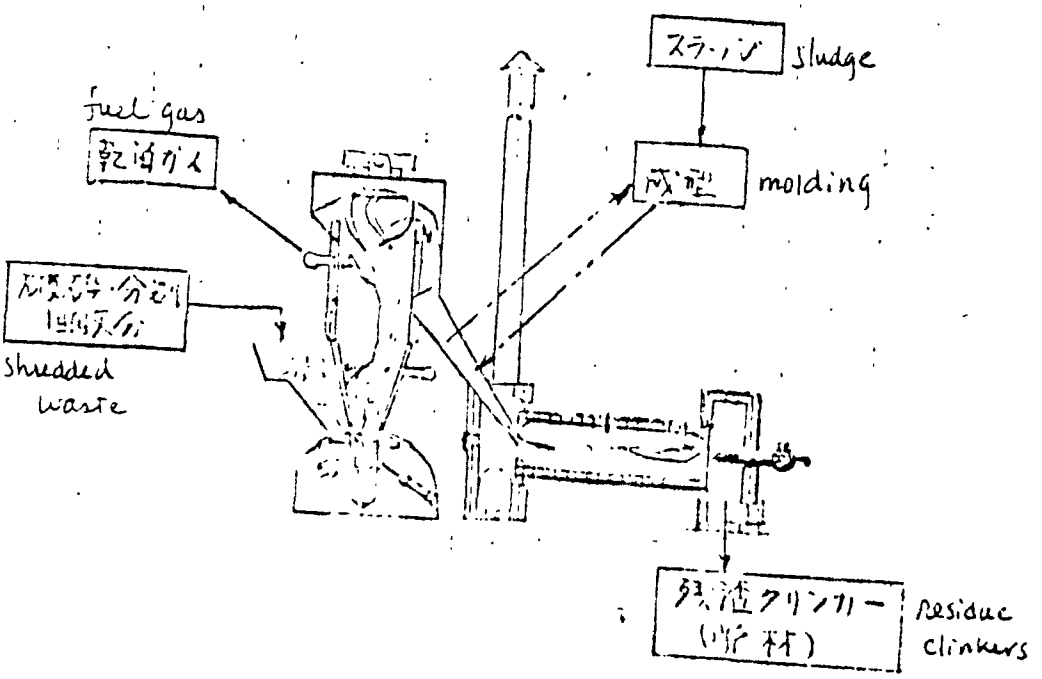
To develop the hybride retort, following research items are pointed out.

(1) A series of gasification experiment with 1 liter retort to predict a precise material balance of the process.

(2) A series of gasification experiment with 15 liter retort to clarify the strength of the charge at a packed state, the permeability of the bed, and the characteristics of heat transfer.

(3) Development of the feed mechanism and the chamber geometory to permit smooth up flow of the charge.

The research of these items has launched to conduct in Naional Chemical Laboratory for Indusry. Based on the performances of these researches, the study will be advanced to pilot plant test.



fuel gas
乾留ガス
スラッジ
sludge
成型
molding
shredded waste
残渣クリンカー
(骨材)
residue clinkers

[illegible]-bed Pyrolysis Process for Oil Recovery

[illegible], Ltd.

MUNICIPAL REFUSE PYROLYSIS
BY FLUIDIZED BED REACTOR

The recovery of oil from municipal refuse is acceptable from user, because the oil is storable and there requires mild reaction condition comparing gas production.

This development program has two major targets as follows;

(1) Yield of the recovered oil is 35 wt.% to the feed by dry basis.

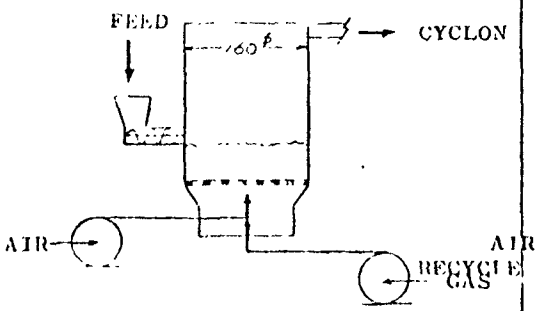
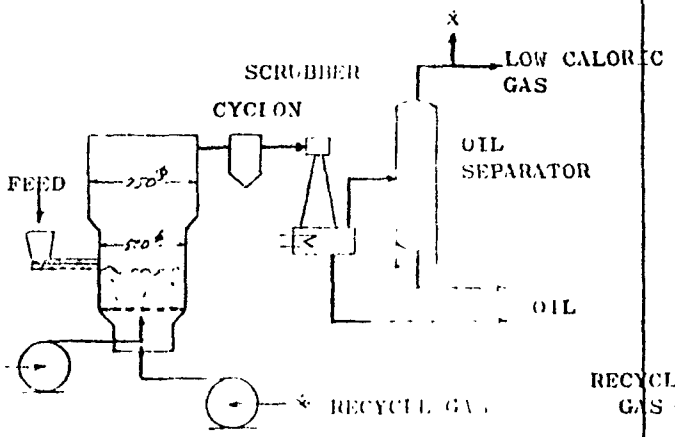
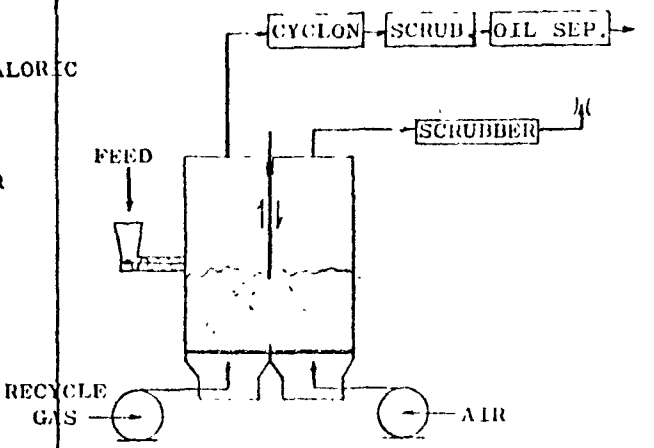
(2) The calorific value of the recovered oil is 8,000 kcal/kg.

This system would have the following features;

(1) Required heat of reaction is supplied by partial oxidation reaction of solid waste and air.

(2) Carrier gas of fluidization consists of a part of produced gas and air. This combination makes it easy to control reaction temperature in the reactor.

MUNICIPAL REFUSE PYROLYSIS
BY FLUIDIZED BED REACTOR

	1973	1974	1975
SPECIFICATION OF TEST PLANT	 160φ SMALL PLANT FEED: SIMULATION REFUSE (Paper, Wood, Plastic) CAPACITY: 10 - 20 kg/Hr	 500φ BENCH SCALE TEST PLANT FEED: ACTUAL MUNICIPAL REFUSE CAPACITY: 150 - 200 kg/Hr	 NEW TYPE REACTOR TEST PLANT FEED: ACTUAL MUNICIPAL REFUSE CAPACITY: 150 - 200 kg/Hr
STUDY ITEM	BASIC STUDY USING SIMULATION REFUSE 1. Oil yield comparison between partial oxidation process and external heating process 2. Process study of recovered gas recycling	BENCH SCALE PLANT STUDY 1. Operation study using actual municipal refuse 1.1 Data gathering(yield, operating condition, effect of moisture, etc.) 1.2 Check of mechanical problem 2. Removal of non burnable material from the fluidized bed	SYSTEM FEASIBILITY STUDY 1. Long range operation 2. Operation study of New Type Pyrolys Reactor 2.1 Calorie up of recovered gas 2.2 Utilization of carbonaceous resi

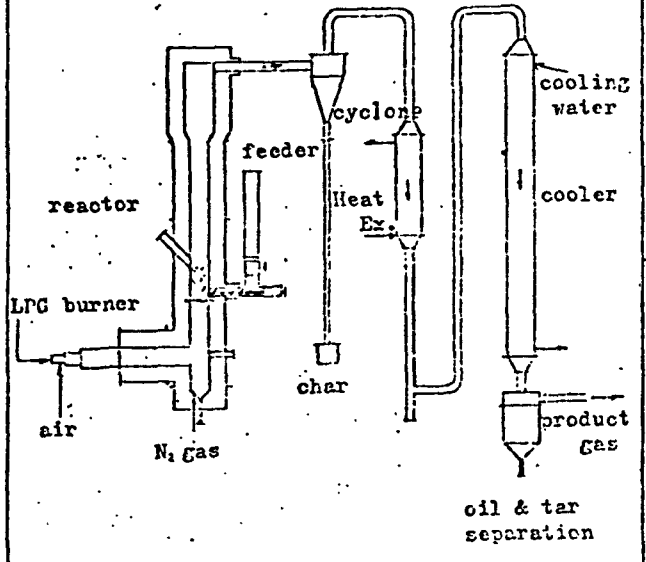
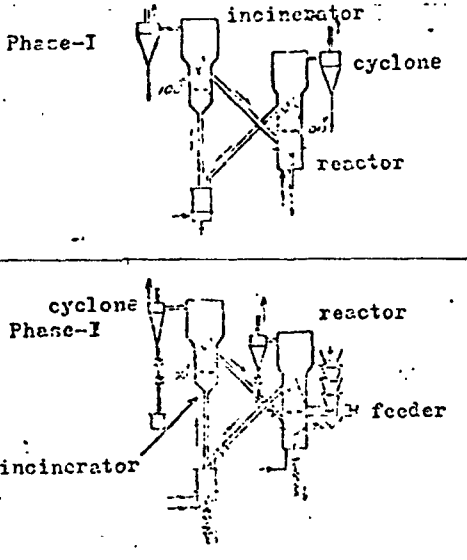
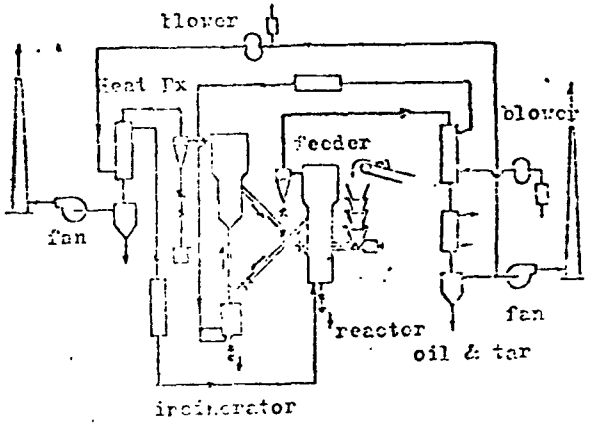
[illegible] Fluidized-Bed Combustion Dual Reactor

[illegible]

[illegible] Heating Co., Ltd.

RESOURCE RECOVERY SYSTEM:
Study of pyrolytic dual fluidized beds system

The aim of this study is to recover useful gas and oil etc. from mainly cellulosic organics in municipal refuse, with pyrolytic fluidized bed reactor.
For the above purpose, a pyrolytic dual fluidized beds system where fluidized medium circulates between an endothermic and exothermic reactor shall be developed.
Main features of this system are;
1) fluidized medium can be cleaned up in an exothermic process, and
2) Heat value of the produced gas can be higher, due to the fact that the pyrolytic process is not influenced by incineration.

	1973	1974	1975
ILLUSTRATION			
ABSTRACT	EXPERIMENTAL RESEARCH ON A PYROLYTIC SINGLE FLUIDIZED BED REACTOR: The following basic data was obtained with a single fluidized bed reactor of 300mm in diameter; a) Compotision and heat value of the test refuse. b) Composition, yield and heat value of pyrolyzed products. c) Endothermic heat, heat & mass balance and yield rate in pyrolytic reaction. d) Influences of gas velocity, bed temperature and size distribution and humidity of the input, upon the composition and yield rate of the products.	EXPERIMENTAL RESEARCH WITH A COLD MODEL OF DUAL FLUIDIZED BEDS SYSTEM: Phase-I: Solid control techniques to minimize gas leakage between two beds shall be examined with a cold model of ca. 100mm in diameter. Phase-II: Continuous refuse feed and residue discharge techniques shall be examined with a cold model of ca. 400mm in diameter.	DEVELOPMENT AND OPERATING RESEARCH OF A PYROLYTIC DUAL FLUIDIZED BEDS SYSTEM: Designing, manufacturing and operating research of a pyrolytic dual fluidized beds system shall be performed. Besides, based on three years research, final evaluation as a back-end system, and total feasibility study shall be summarized.

SECOND U.S.-JAPAN CONFERENCE ON SOLID WASTE MANAGEMENT
Washington, D.C. September 25, 1974

COMMUNIQUE

The Second U.S.-Japan Conference on Solid Waste Management was held in Washington, D.C. September 24 and 25, 1974.

The Japanese delegation, headed by Mr. Tsutomu Fukuda, Director, Waterworks and Environmental Department, Environmental Sanitation Bureau, Ministry of Health and Welfare, was composed of four national government officials and one local government official.

The U.S. delegation, headed by Mr. H. Lanier Hickman, Director of Operations, Office of Solid Waste Management Programs, U.S. Environmental Protection Agency, was composed of five EPA officials and one representative each from the American Public Works Association and the National Solid Waste Management Association. Mr. Fitzhugh Green, Associate Administrator for International Activities, EPA; Mr. Roger Strelow, Assistant Administrator for Air and Waste Management, EPA; and Mr. Arsen Darnay, Deputy Assistant Administrator for Solid Waste Management Programs greeted the Japanese delegation and delivered opening remarks of welcome.

In addition to the conference in Washington, the

Japanese delegation visited various sites demonstrating EPA's solid waste programs in Baltimore, Maryland; St. Louis, Missouri; Memphis, Tennessee; Orlando, Florida; Atlanta, Georgia; and San Francisco, California.

The U.S.-Japanese Conference on Solid Waste Management grew out of the Second U.S.-Japanese Ministerial Conference on Environmental Pollution held in Washington, D.C. in June 1971 between then Chairman of the Council on Environmental Quality Russell Train, and Japanese Minister Sadanori Yamanaka. The First Conference on Solid Waste Management was held in Tokoyo in 1973.

During the Conference, the two delegations presented papers and exchanged information on various aspects of the solid waste problems confronting each country. Principal topics were collection and transportation of wastes, disposal of wastes, hazardous waste management, and resource recovery. The discussions were vigorous and both sides agreed that the exchange was very useful.

In order to expand U.S.-Japan cooperation on problems of solid waste management, the two delegations agreed to begin to focus on technical areas of solid waste management which could lead to future joint projects which could result in improved solid waste management and environmental protection. Study areas which will receive greater attention during the next 18 months include:

1. Pyrolysis of solid waste.

2. Environmental effects of vinyl chloride and PVC.
3. Improved collection systems management and technology.
4. Environmental effects of improper disposal of solid waste on the land.
5. Hazardous waste treatment and disposal technology.
6. Recovery of post-consumer solid waste.

Technical staff of the two governments will begin detailed discussions and communications in the selected study areas as the first step in identifying specific efforts which can benefit the cooperating countries. Each country will identify specific technical experts to begin such efforts under the guidance of the project leaders _____ of the Japanese government and H. Lanier Hickman, Jr. of the U.S. EPA's Office of Solid Waste Management Programs.

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FOR IMMEDIATE RELEASE FRIDAY, SEPTEMBER 27, 1974

U.S., JAPAN ANNOUNCE SOLID WASTE AGREEMENT

U.S. and Japanese government officials announced agreement today on a plan which could lead to future joint projects concerning solid waste management, resource recovery and environmental protection.

The announcement followed the Second U.S. Japan Conference on Solid Waste Management which was held at Environmental Protection Agency headquarters in Washington, D.C. September 24-25.

Experts in solid waste management from the two countries will begin detailed communications in a number of study areas as the first step in identifying cooperative activites which can benefit the United States and Japan, the announcement said.

The study areas which will receive attention during the coming months include:

Pyrolysis of solid waste. This is the use of solid waste as energy through a process involving the physical and chemical decomposition of organic matter by the action of heat in an oxygen deficient atmosphere.

Environmental effects of vinyl chloride and polyvinyl chloride; improved collection systems management and

(more)

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EPA FORM 1510-1 (REV. 8-72)

technology; environmental effects of improper disposal of solid waste on the land; hazardous waste treatment and disposal technology; recovery of post consumer solid waste; and management information systems in industrial wastes.

The Japanese and U.S. delegates decided that a third conference will be held in Japan in late 1975 or early 1976.

The Japanese delegation was headed by Tsutomu Fukuda, Director, Waterworks and Environment Department, Environmental Sanitation Bureau, Ministry of Health and Welfare.

The other delegates from the national Japanese government were: Tadayuki Morishita, Deputy Chief, Industrial Waste Management Office, Ministry of Health and Welfare; Michio Nakajiku, Research and Development Office, Agency of Industrial Science and Technology, Ministry of International Trade and Industry; Mitsuo Nakano, Head, Road Division, City Bureau, Ministry of Construction.

The fifth member of the delegation was Takashi Miyanohara, Sanitation Bureau, Yokohama City.

The U.S. delegation, headed by H. Lanier Hickman, Director of Operations, Office of Solid Waste Management Programs, EPA, was composed of five EPA officials and one representative each from the American Public Works Association and the National Solid Waste Management Association.

Fitzhugh Green, Associate Administrator, EPA; Roger Strelow Assistant Administrator for Air and Waste Management, EPA; and Arsen Darnay, Deputy Assistant Administrator for Solid Waste Management Programs, EPA; greeted the Japanese delegation and delivered opening remarks of welcome.

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