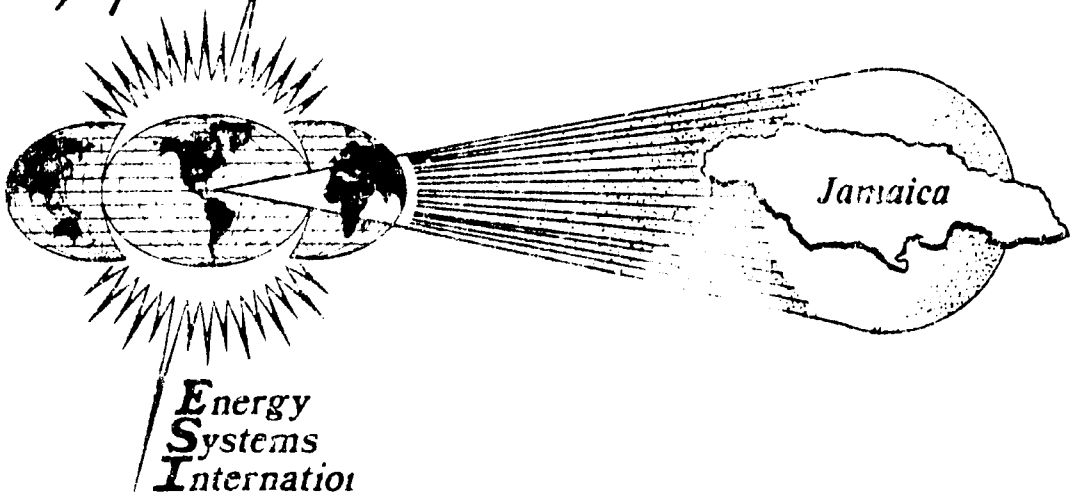
JM
333.79
E56
v. 3, part 4

PN-AAJ-427
PB82-249566
ESI
REPORT NO.
EA-80-0101-3d



Preliminary Energy Sector Assessments
Jamaica

Volume III
Renewable Energy:

Solar Energy — Commercial & Industrial
Solar Energy — Agricultural
Biogas Applications
Energy Conversion From Waste

Prepared For

Department of State
U.S. Agency for International Development

Under Contract No. AID-532-79-11

JANUARY 1980

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA 22161

PRELIMINARY
ENERGY SECTOR ASSESSMENTS OF JAMAICA

PB82-249566

CHAPTER 6

ENERGY CONVERSION FROM WASTE

for

UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT

CONTRACT NUMBER AID 532-79-11

TASK 7

ENERGY SYSTEMS INTERNATIONAL
8301 GREENSBORO DR., SUITE 30
MCLEAN, VIRGINIA 22102

JANUARY 1980

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO. PN-AAJ-427	2.	3. Recipient's Accession No. PB82 249566

4. Title and Subtitle Preliminary Energy Sector Assessments of Jamaica Volume III: Renewable Energy: Part IV: Energy Conversion from Waste

5. Report Date January 1980

6.

7. Author(s)

8. Performing Organization Rept. No. EA-80-0101-3d

9. Performing Organization Name and Address

Energy Systems International
8201 Greensboro Drive, Suite 30
Mclean, VA 22102

10. Project/Task/Work Unit No.

11. Contract(C) or Grant(G) No.
(C) AID-532-79-11
(G)

12. Sponsoring Organization Name and Address

United States Agency for International Development
Washington, D.C. 20523

13. Type of Report & Period Covered

14.

15. Supplementary Notes The other volumes in this study are available as: SET: PB82-249509
I: Executive Summary: PB82-249517
II: Economic Assessment/ PB82-249525
IIIA: Solar Energy, Comm & Ind: PB82-249533
IIIB: Solar Energy, Agri: PB82-249541
IIIC: Biogas Applications: PB82-249558
IV: Coal Prefeasibility Study: PB82-249574
V: Electric Utility Rates: PB82-249582

16. Abstract (Limit: 200 words)

Because heavy dependence on costly imported fuel is greatly hindering Jamaica's economic growth, USAID Jamaica and the Government of Jamaica sponsored a preliminary assessment to identify viable alternative energy options. Technological studies were published in three volumes (with volume three being in four parts, for a total of six volumes), to which two introductory volumes were added, providing, respectively, an executive summary of the entire assessment and an economic assessment of the individual areas. This study, the fourth part of the first technical volume, considers the feasibility of energy conversion from wastes. Specifically, the study analyzes the potential for energy recovery from urban wastes in Jamaica, with the Kingston area serving as a case study, and assesses the feasibility of building a prototype demonstration unit for energy recovery from solid wastes at the University of the West Indies (UWI)-Mona Campus. Steam-generating waterwall combustion, refuse-derived fuel systems, pyrolysis, anaerobic biological conversion (biogas), and gas recovery from landfills are discussed as alternative systems for energy recovery from urban wastes. It is concluded that the only practical alternative for use in Kingston is waterwall combustion. This program could be cost-effective, but cannot currently be applied because of inefficient and unreliable refuse collection. It is therefore recommended that a detailed study be made of the physical, management, and sociological aspects of the refuse collection problem. With respect to a demonstration program at UWI-Mona Campus, it is concluded that biogas generation would be the only suitable process given the size of the program's waste treatment plant. However, because of the heterogeneous nature of urban wastes and the low efficiency of the recovery process, this method will probably not have widespread urban usage. It is therefore recommended that UWI's Mona Campus not proceed with a field-scale biogas generation demonstration unit, but rather that it be financially assisted in developing a laboratory to study various energy alternatives. Appendices include a 9-item bibliography (1968-79) and a summary of a splinter group discussion.

17. Document Analysis a. Descriptors

b. Identifiers/Open-Ended Terms

Developing Country Application

c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
Release Unlimited	Unclassified	
	20. Security Class (This Page) Uncalssified	22. Price

(See ANSI-Z39.18) See Instructions on Reverse

OPTIONAL FORM 272 (4-77)
(Formerly NTIS-35)
Department of Commerce

BIBLIOGRAPHIC DATA SHEET	1. CONTROL NUMBER PN-AAJ-427	2. SUBJECT CLASSIFICATION (695) AP00-0000-G326

3. TITLE AND SUBTITLE (240)

Preliminary energy sector assessments of Jamaica, v. 3, renewable energy: energy conservation from waste

4. PERSONAL AUTHORS (100)

5. CORPORATE AUTHORS (101)

Energy Systems Int.

6. DOCUMENT DATE (110)	7. NUMBER OF PAGES (120)	8. ARC NUMBER (170)
1980	60p.	JM333.79.E56

9. REFERENCE ORGANIZATION (130)

ESI

10. SUPPLEMENTARY NOTES (500)

(Set includes: PN-AAJ-422 - PN-AAJ-429)

11. ABSTRACT (950)

12. DESCRIPTORS (920)

Jamaica
Energy
Biogass
Waste conversion
Alternative energy
Anaerobic processes
Conservation
Pyrolysis
Efficiency
Renewable resources
Solids

13. PROJECT NUMBER (150)

14. CONTRACT NO.(140)

AID-532-79-11

15. CONTRACT TYPE (140)

16. TYPE OF DOCUMENT (160)

AID 590-7 (10-79)

FOREWARD

The eight reports of the Preliminary Energy Sector Assessments of Jamaica conducted by the United States Agency for International Development Energy Team are contained in the following five volumes:

Volume	I	Executive Summary
	II	Economic Assessment
	III	Renewable Energy:
		(a) Solar Energy - Commercial & Industrial
		(b) Solar Energy - Agricultural
		(c) Biogas Applications
		(d) Energy Conversion from Waste
	IV	Coal Prefeasibility Study
	V	Electric Utility Rate Analysis

These studies were initiated by the USAID in conjunction with the Government of Jamaica to further the objectives of Jamaica's Five Year Development Plan and its Energy Sector Plan. The studies also represent USAID's first energy assessment of a developing country.

Due to the diverse technology requirements and the high degree of specialization required by each of the studies, a United States Energy Team of experts was assembled. The individual team members were selected based upon a demonstrated balance between academic and "hands-on" experience in the specific study area.

Energy Systems International (ESI), had overall responsibilit for systems planning, project management and integration of all elements of the Preliminary Energy Sector Assessments.

These reports should not be considered as the final product of any study area, but as baseline documents to be used for identifying specific energy programs and projects for implementation in the near-term to assist Jamaica in allevi ating its critical energy problem.

Any comments or questions concerning this study should be directed to:

Energy Systems International
8301 Greensboro Drive, Suite 30
McLean, Virginia 22102
(703) 827-0303
Telex: 903039

ACKNOWLEDGMENTS

The success of the Preliminary Energy Sector Assessments of Jamaica was assured through the joint cooperation, professionalism, competence and diligence of the entire U.S. Energy Team and their key Jamaican counterparts. The assessment was a concentrated effort over a fifteen week period in Kingston, Jamaica, during which many government agencies, institutions, private sector organizations and individuals became involved and generously supported study development. The many excellent people involved are too numerous to mention herein, but a few have been singled out for recognition because their outstanding effort and support helped to provide study continuity and progress.

Special thanks go to Dr. Henry G. Lowe, Director, Energy Division of the Ministry of Mining and Natural Resources and to the MMNR staff for providing the inspiration and leadership from the Jamaican side to ensure that there was enthusiastic support and contributions to this study from all Jamaican counterparts. A special note of appreciation goes to Dr. Gerald Lalor, Pro-Vice Chancellor, the University of the West Indies - Mona Campus and to the UWI-Mona Campus staff for their technical dedication and collaboration with the energy team during the Energy Conversion from Waste Study.

Special thanks must also be given to the United States Agency for International Development, in particular, Mr. Jerome Hulehan, General Development Office, USAID Kingston, Jamaica Mission and Dr. Jerome Bosken, Deputy Director, Energy Office, USAID Headquarters, Washington, D.C., for their encouragement and support of the project and for their assistance throughout the study.

Most importantly, special acknowledgment is given to those who took the time to make important contributions to the study through their interviews and discussions with the U.S. Energy Team members. Some of these people and organizations are identified on pages 6-27 and 6-28 of this Chapter.

CREDITS

The principal investigator for this study was Dr. Richard R. Dague of the University of Iowa. Dr. Dague spent one month in Jamaica in his study effort. Energy Systems International integrated the report with the other studies and was responsible for format of contents as well as typing, editing, and publishing the document.

√

TABLE OF CONTENTS

PAGE

6.1 EXECUTIVE SUMMARY.....6- 1
6.1.1 Introduction.....6- 1
6.1.2 Terms of Reference.....6- 1
6.1.3 Background Information.....6- 1
6.1.4 Study Method.....6- 3
6.1.5 Findings.....6- 3
6.1.6 Conclusions and Recommendations.....6- 5

6.2 INTRODUCTION.....6- 7

6.3 TERMS OF REFERENCE.....6- 8
6.3.1 Objectives.....6- 8
6.3.2 Schedule.....6- 9

6.4 BACKGROUND INFORMATION.....6-10
6.4.1 Urban Solid Wastes as a Fuel.....6-10
6.4.2 Recovery Alternatives.....6-11
6.4.2.1 Waterwall Combustion.....6-11
6.4.2.2 Refuse Derived Fuel (RDF).....6-13
6.4.2.3 Pyrolysis.....6-15
6.4.2.4 Anaerobic Biological Conversion (biogas).....6-19
6.4.2.5 Landfill with Gas Recovery.....6-25
6.4.3 Process Efficiencies.....6-26

6.5 STUDY METHOD.....6-27
6.5.1 Personnel Interviewed.....6-27
6.5.2 Sites Visited.....6-28
6.5.3 Pertinent Data Reviewed.....6-28

6.6 FINDINGS.....6-30
6.6.1 Energy Recovery Alternatives in Jamaica.....6-30
6.6.2 Kingston Metropolitan Region.....6-30
6.6.2.1 Refuse Production and Collection.....6-30
6.6.2.2 Waterwall Combustion in Kingston.....6-31
6.6.2.3 Biogas Application in Kingston.....6-32
6.6.3 Biogas Application in Small Jamaican Cities.....6-33
6.6.4 University of the West Indies - Mona Campus Energy Involvement.....6-34
6.6.4.1 Background.....6-34
6.6.4.2 Demonstration Alternatives.....6-34
6.6.4.3 Design of Biogas Demonstration Facility.....6-35

PAGE

6.7 DISCUSSION OF FINDINGS.....6-37
6.7.1 Urban Solid Wastes - Kingston.....6-37
6.7.2 University of the West Indies - Mona Campus Demonstration.....6-38
6.7.3 University of the West Indies - Mona Campus Laboratory.....6-39

6.8 CONCLUSIONS AND RECOMMENDATIONS.....6-41
6.8.1 Urban Solid Wastes - Kingston.....6-41
6.8.2 University of the West Indies - Mona Campus.....6-41

6.9 REFERENCES.....6-42

6.10 APPENDICES.....6-43
A. Terms of Reference.....6-44
B. Final Report Conference - Splinter Group Discussion.....6-45

LIST OF TABLES

TABLE	TITLE	PAGE
6-1	Gas Production	6-23
6-2	Gas Composition at 35°C and 60°C	6-2[illegible]
6-3	Volatile Solids Destruction	6-23
6-4	Comparison of Energy Recovery Efficiencies from Various Solid Waste Energy Recovery Processes	6-24

LIST OF FIGURES

FIGURES	TITLE	PAGE
6-1	Typical Waterwall Furnace for Unprocessed Solid Wastes	6-12
6-2	Simplified Flow Diagram of Dry Processing Approach	6-14
6-3	Monsanto Landgard System	6-16
6-4	Union Carbide Purox System	6-17
6-5	Biological Gasification of Solid Wastes in Reactors	6-20
6-6	Production of Electricity from Landfill Gas	6-25

6.1 EXECUTIVE SUMMARY

6.1.1 Introduction

The economic recovery of energy and materials from urban wastes has been of interest to public works officials for many years. In general, the recovery of resources from urban wastes has not been successful. The value of recovered resources has not been sufficient to offset the added costs of recovery efforts.

Increases in the price of fuels in recent years have led to renewed interest in energy recovery from urban wastes. Several research and demonstration projects are underway in the United States and other countries to evaluate the potential of energy recovery from solid wastes.

This report will center on the application of various approaches to energy recovery from urban wastes in Jamaica and how such approaches might best be demonstrated.

6.1.2 Terms of Reference

The principal thrust of this study was to assess the feasibility of a prototype demonstration unit for energy recovery from the solid wastes generated on the Mona Campus of the University of the West Indies (UWI), Kingston, Jamaica. Discussions with various Jamaican officials led to an expansion of the scope of the study to include an analysis of the potential for energy recovery from urban wastes in Jamaica with the Kingston area serving as a case study.

6.1.3 Background Information

6.1.3.1 Urban Solid Wastes as a Fuel

The use of urban solid wastes as a fuel will not solve the energy problems of any country. In the United States, for example, the recovery of the heat value in all of the 200 million tons of urban solid wastes generated annually would provide only two to three percent of the 75 quadrillion (75×10^{15}) Btu of total annual energy consumption.

Energy consumption on a per capita basis in Jamaica is about 13 percent of what it is in the United States. Data indicates

that the per capita generation of urban wastes is also lower in Jamaica. Based on the Kingston urban area, indications are that the energy available in urban solid wastes in Jamaica, as a percentage of total energy consumption, may be in about the same range (two to three percent) as in the United States.

The point is, the energy available in urban wastes is really quite small, regardless of the location. Nevertheless, most countries can ill afford to ignore any material that may help to reduce petroleum consumption.

6.1.3.2 Recovery Alternatives

Alternatives for the recovery of fuels or energy from urban solid wastes may be classified as thermal, biological, or mechanical. Specific types of systems that have been applied to energy recovery from urban wastes are:

(1) Waterwall Combustion
(2) Refuse Derived Fuel (RDF)
(3) Pyrolysis
(4) Anaerobic Biological Conversion (Biogas)
(5) Landfill with Gas Recovery

The only system in the above list that is beyond the experimental stage is waterwall combustion. All the other alternatives will work, but have not been proven on a wide scale.

6.1.3.2.1: Waterwall combustion involves the burning of refuse as received without prior separation of non-combustibles. Heat recovery and steam generation are the principal end products. The steam may be used for some nearby industrial need or for the generation of electricity.

6.1.3.2.2: The Refuse Derived Fuel (RDF) systems are highly mechanized, involving shredders, separators, classifiers, and other maintenance-intensive components which separate and process the combustibles (the fuel) and the non-combustibles (metals, glass, etc.). An advantage of the RDF approach is that the fuel produced may be transported for use at a distant site. The RDF is often mixed with another fuel such as coal, for burning in industrial boilers.

6.1.3.2.3: Pyrolysis involves the heating of organic matter in an atmosphere devoid of, or deficient in, oxygen. The goal is the destructive distillation of the

complex organics and the production of gaseous, liquid or solid fuels. Several systems have been under development and demonstration in the United States and elsewhere. It can be concluded that pyrolysis is a process that is well understood, but the technology has not been well demonstrated for application to complex mixtures of materials such as urban refuse.

6.1.3.2.4: The anaerobic biological (biogas) process for the conversion of organic matter to methane and carbon dioxide is another alternative for the recovery of energy from wastes. The process has been applied for over 60 years in the stabilization of sludges in waste-water treatment. The process is well understood, but has not been widely applied to urban solid wastes. A demonstration project requiring 50 to 100 tons per day is underway at Pompano Beach, Florida.

6.1.3.2.5: Another approach that is being evaluated for energy recovery from urban solid wastes is the recovery of combustible gases from sanitary landfills. As a practical matter, attempts to recover methane from landfills may only complicate an otherwise simple method of refuse disposal.

6.1.4 Study Method

An important element of the urban wastes study was discussions with various individuals in the national and local governments of Jamaica and the University of the West Indies, Mona Campus. Tours of various facilities in the Kingston urban area, including the UWI campus, that could have potential for or be involved in energy recovery from urban wastes were conducted. To gain a better feeling for the urban wastes situation in other cities of Jamaica, a 600 mile auto tour of the island was conducted. Also, several reports dealing with the energy situation in Jamaica and with urban solid wastes were reviewed.

6.1.5 Findings

6.1.5.1 Urban Solid Wastes - Kingston

One element of this study was the evaluation of energy recovery from urban wastes using the Kingston area as a case study. From a review of previous reports, discussions with individuals, and personal observations it was apparent that there is a problem with refuse

collection in the Kingston urban area. A 1979 report on solid wastes management in the Kingston Metropolitan Region (KMR) by consultants to the National Planning Agency (NPA) indicated that about 1000 tons per day (TPD) of urban solid wastes are generated in the KMR. Of the 700 tons generated daily in the Kingston and Saint Andrew Corporation (KSAC) the consultants estimated that only about 130 TPD of refuse is actually collected and transported to disposal sites. Although some individuals mentioned in discussions that the 130 TPD figure appeared low, there is a serious problem in the reliable collection of refuse in the Kingston area.

The consultants to the NPA estimated that the capital and annual operation and maintenance (O&M) costs required to implement a new solid wastes collection system in the KSAC and St. Catherine and St. Thomas areas would be U.S. $12 million and $8 million, respectively.

Capital costs estimation for a waterwall incinerator with steam generation capabilities would be U.S. $40 million for a 1000 TPD facility. Operation and maintenance costs would likely average about U.S. $10 per ton of refuse processed. Annual costs for such a facility to handle the 1000 TPD of urban solid wastes generated in the KMR are estimated as follows:

Annual Capital Costs (U.S. $40 million,20 yr,8%)	$4,074,000
Annual Operation and Maintenance (U.S. $10 per ton of wastes)	3,650,000
TOTAL ANNUAL COSTS	U.S. $7,724,000

The annual costs for new equipment and operational costs to bring the refuse collection system to the required level of efficiency, as proposed by the consultants to the NPA, are:

Annual Capital Costs (U.S. $12 million,10 yr, 8%)	$1,788,000
Annual Operation and Maintenance	8,000,000
TOTAL ANNUAL COSTS	U.S. $9,788,000

The annual cost of a waterwall combustion system, including O&M, is about equal to the value of the energy in the urban solid wastes generated in the KMR. If the solid wastes were

being collected in an efficient and reliable manner, it would be feasible from an energy and economic standpoint to proceed with a more detailed study and plans for a waterwall incineration/steam generation facility in Kingston.

6.1.5.2 University of the the West Indies - Mona Campus Demonstration

Another part of this study was a feasibility assessment of an energy recovery demonstration at the Mona Campus of the University of the West Indies. About 1000 pounds per day of refuse is generated by the University and hauled for burning in incinerators at the site of the University's wastewater treatment plant.

The only energy recovery alternative that was considered to be reasonable for a field-scale demonstration was the anaerobic digestion (biogas) approach. Calculations indicate that a biogas reactor with a volume of 864 cubic feet would be required to produce 360 cubic feet of gas per day from a daily feed of 90 pounds (dry weight) of organic refuse. This would be sufficient gas production to serve as fuel for a one-horsepower internal combustion engine operating 24 hours per day.

6.1.6 Conclusions and Recommendations

(1) Based on the analysis of the potential for energy recovery from urban solid wastes in the Kingston Urban Region, it is concluded that the only technical alternative worthy of consideration is waterwall incineration with steam generation. Based solely on the value of the refuse as a fuel (U.S. $7.4 million per year) versus the cost of recovery by waterwall incineration (U.S. $7.7 million per year), it appears feasible to proceed with energy recovery in Kingston. This cannot be done, however, since the urban solid wastes are not being collected. It is recommended that a detailed study be made of the urban solid wastes collection problem in Kingston and that a detailed evaluation of alternatives for energy recovery be considered. It is estimated that this study would cost approximately U.S. $150,000.

(2) The results of this study indicate that the University of the West Indies should not proceed with a field-scale anaerobic digestion demonstration unit. It is recommended that the University center its energy interests on the establishment of a properly-equipped laboratory to be devoted to research and demonstration of energy alternatives. Establishment of such a laboratory would cost an estimated U.S. $182,500.

6.1.6.1 Recommended Energy Conversion from Waste Program

Based on the recommendations cited above only two programs were defined as follows:

(1) A detailed study on waste collection problems in Kingston and an evaluation of the alternatives for energy recovery;

(2) The establishment of an Alternative Energies Laboratory at the University of the West Indies - Mona Campus.

6.2 INTRODUCTION

The economic recovery of materials and/or energy from urban wastes has been a goal of public works officials for many years. With few exceptions, such efforts have not been successful. In most cases, it has been less costly to "dispose" of wastes rather than to attempt materials or energy recovery.

From about 1973 to the present, the peoples of the world have been coming to the realization that the earth's supply of fossil fuels is finite and rapidly disappearing. Rapid increases in the price of oil have led to increases in the costs of production in the developed countries. These, in turn, have contributed to an inflation of the prices of goods and services. As discussed by Dr. Trevor A. Byer[1] the developing countries, of which Jamaica is a prime example, experience a double impact when energy costs rise. There is not only the inflationary effect of rising fuel costs, but also the negative impact of the inflated costs of imported manufactured goods.

The energy problems facing many countries of the world have resulted in increased efforts to conserve fuels and to develop alternative energy sources. One alternative source of energy is urban wastes. This report will center on the potential for energy recovery from wastes in Jamaica.

6.3 TERMS OF REFERENCE

6.3.1 Objectives

The original Terms of Reference, as presented in the Statement of Work on Contract No. AID-532-79-11 for Task 7 - Energy Conversion from Wastes, are listed in Appendix A.

As a result of discussions with individuals in the Jamaican Government, the UWI, and the Scientific Research Council, it was concluded that Task 7 should not be limited to an evaluation of an energy recovery demonstration project at the UWI-Mona campus, but should evaluate the wider context of energy recovery alternatives and proposals for energy recovery from urban wastes, especially in the Kingston Urban Region.

It was also pointed out that a "detailed estimate of the costs", as stated in the Terms of Reference, would be most difficult to accomplish with any degree of reliability without an accompanying detailed design of the system.

In addition to the tasks contained in the specific study Terms of Reference, the Energy Team members were also responsible for the completion of the requirements outlined in the Project Management and Detailed Study Plan (discussed in Chapter 1). The team members were to conduct, during the course of the study, three assessment reviews to ensure that timely progress checks and necessary study plan alterations were made. The team members were also requested to make two presentations. The first was a seminar to be held midway through the assessment; the second to be at study completion in which the results, conclusions and recommendations were highlighted at the Final Report Conference.

As a result of the project summary given during the first day of the conference, a number of questions were asked to clarify study procedures, options, constraints and considerations made when formulating specific recommendations. The questions were fielded by the team experts and Jamaican counterparts during splinter group discussions held the second day. The tapes of the splinter group questions and answer session were transcribed and are contained in Appendix B.

6.3.2 Schedule

Task 7, Energy Conversion from Wastes, was originally scheduled for a four-week effort from August 23, 1979, through September 20, 1979. As a result of a decision to hold a two-day conference on November 13 and 14, 1979, in Kingston, a one-week extension of time was added to Task 7 to cover travel, preparation, and participation in the conference.

6.4 BACKGROUND INFORMATION

6.4.1 Urban Solid Wastes as a Fuel

The recovery of fuel from urban wastes will not "solve" the energy problems of any country. However, the same can also be said of any one of the commonly mentioned alternative energy sources (solar, wind, geothermal, etc.) The amount of energy that can be recovered from wastes is small in comparison to total energy needs.

To illustrate the point made, it is interesting to compare the potential for energy recovery from urban wastes in the United States with that of Jamaica. In the United States in 1974, some 212 million people were consuming about 73 x 10^{15} Btu of energy for all purposes, or about 365 million Btu per capita per year[2]. At the same time, Americans were generating about 1800 pounds per capita per year of municipal refuse with an average heat value of about 5000 Btu per pound. If Americans were to recover all of the energy available in their urban wastes, it would amount to about 2.5 percent of total energy consumption. Obviously, energy recovery from urban wastes is not "the" solution to U.S. energy problems.

The Ministry of Mining and Natural Resources supplied data from 1978 which indicates a total petroleum consumption of 15.751 million barrels of fuel oil equivalents (one fuel oil equivalent is equal to 5.984 million Btu), or a total of 9.425 x 10^{13} Btu per year[3].

Though limited accurate data on urban waste generation in Jamaica is available, a recent study of the Kingston Metropolitan Region[4] indicated a solid waste generation rate of 1000 tons per day, amounting to 2.8 pounds per capita for the 723,000 people of the region. The report indicated an average heat value for the refuse of 3000 Btu per pound.

If the entire population of Jamaica were generating refuse at the same rate and of the same character as that of the Kingston Metropolitan Region, the potential energy in the urban refuse of the 2.14 million residents of Jamaica would be 3.06 million Btu per capita per year. This is about six percent of total per capita energy consumption.

The people in the rural areas of Jamaica, however, are probably not discarding refuse at the same rate as those in Kingston or other Jamaican cities. Even if the national average refuse generation rate is only half that assumed,

the urban waste generated in Jamaica could represent a potential for energy recovery amounting to two or three percent of total energy consumption. This would indicate that there is little difference, on a percentage basis, between Jamaica and the U.S. from the standpoint of the potential of energy recovery from urban wastes.

The real potential of urban wastes as a source of energy recovery is not great in either the developed or developing countries. Nevertheless, if net energy recovery amounts to only one percent of total energy consumption, the recovery of energy from urban solid wastes should be considered. Each urban area must be assessed to determine the cost and energy effectiveness of applying various energy and materials recovery alternatives.

6.4.2 Recovery Alternatives

The basic processes of energy and materials recovery from urban refuse may be classified as thermal, biological, and mechanical. In general, thermal processes include direct incineration with heat recovery and pyrolysis for the production of gaseous, liquid, or solid fuels. Biological processes include anaerobic digestion for the production of a fuel gas, primarily methane and carbon dioxide. Mechanical systems include shredding (size reduction) and a variety of operations aimed at separating the various components of the refuse, such as metals, glass, paper, etc. The principal energy recovery systems are as follows:

(1) Waterwall Combustion with Steam Generation
(2) Refuse Derived Fuel (RDF)
(3) Pyrolysis
(4) Anaerobic Biological Conversion (Biogas)
(5) Landfill with Gas Recovery

The characteristics, fundamentals, and efficiencies of these systems have been presented and discussed in detail by Steven J. Levy and H. Gregor Rigg in a report by the U.S. Environmental Protection Agency.[5]

6.4.2.1 Waterwall Combustion

A typical waterwall furnace for the combustion of unprocessed municipal solid waste is shown in Figure 6-1. As indicated, the refuse is fed onto mechanical grates where it burns as it moves through the furnace. Noncombustible residue is collected for disposal or recovery of metals and ash. Heat radiated by the burning waste is

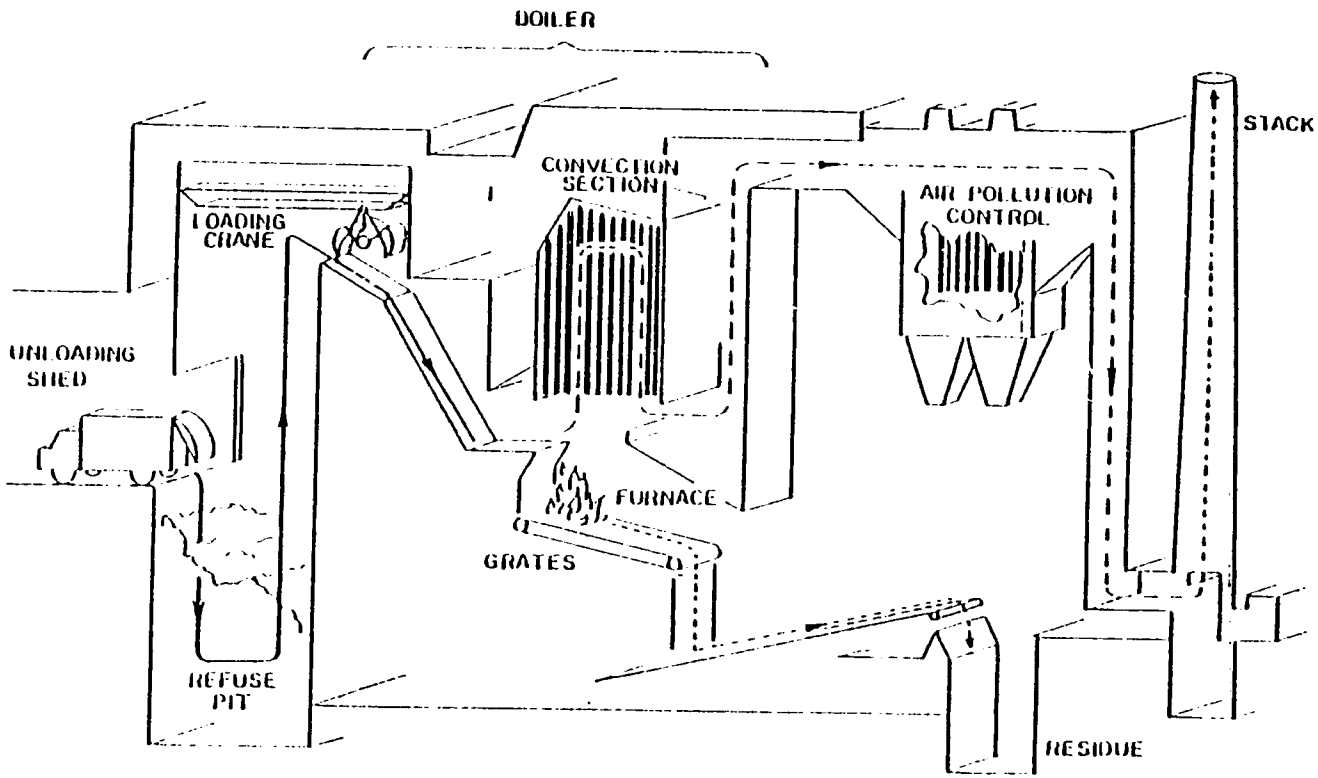


FIGURE 6-1

Typical Waterwall Furnace for Unprocessed Solid Waste

recovered by integrally constructed boilers, generating steam while reducing the temperature of exhaust gases. The efficiency of heat recovery in the waterwall combustion system is about 59 percent.[5]

Waterwall combustion is the most widely applied approach to the recovery of energy from urban solid wastes. Several hundred units in sizes ranging from 60 to 2600 tons per day have been built in Europe and Japan. Some 10 plants have been built in the United States and Canada since 1967.[5]

The principal advantage of waterwall combustion for energy recovery, compared with the other alternatives, is that the necessity for an expensive and maintenance-intensive "front end" system is avoided. Also, a comparatively high percentage of the heat value of the raw refuse can be recovered as steam.

A disadvantage of waterwall combustion is that there is the potential for air pollution, especially with regard to particulates. Another factor that must be considered in design is the increased potential for the corrosion of boiler tubes as a result of certain components, especially plastics, commonly found in mixed municipal refuse. Waterwall combustion is by far the most reliable and proven technology for the recovery of energy from urban refuse, as compared to the alternatives discussed below.

6.4.2.2 Refuse Derived Fuel (RDF)

Another alternative for the recovery of energy from urban refuse is the production of a fuel that may be burned at a nearby or remote site. A flow diagram for such a system is shown in Figure 6-2.

An important aspect of the production of RDF is the size reduction and separation operations making up the front end of the system. This, of course, involves greater costs and maintenance requirements, compared to the direct incineration of unprocessed refuse. But the shredding and separation operations also enhance the potential for the recovery of metals and other materials and improve the consistency and quality of the fuel.[5] An advantage of the RDF approach is that the refuse processing does not bear the capital, operational, and maintenance costs of the steam generation equipment that is involved in waterwall combustion with steam generation. On the other hand, any added costs incurred by the customer as a result of using the RDF will detract from the value of the fuel.

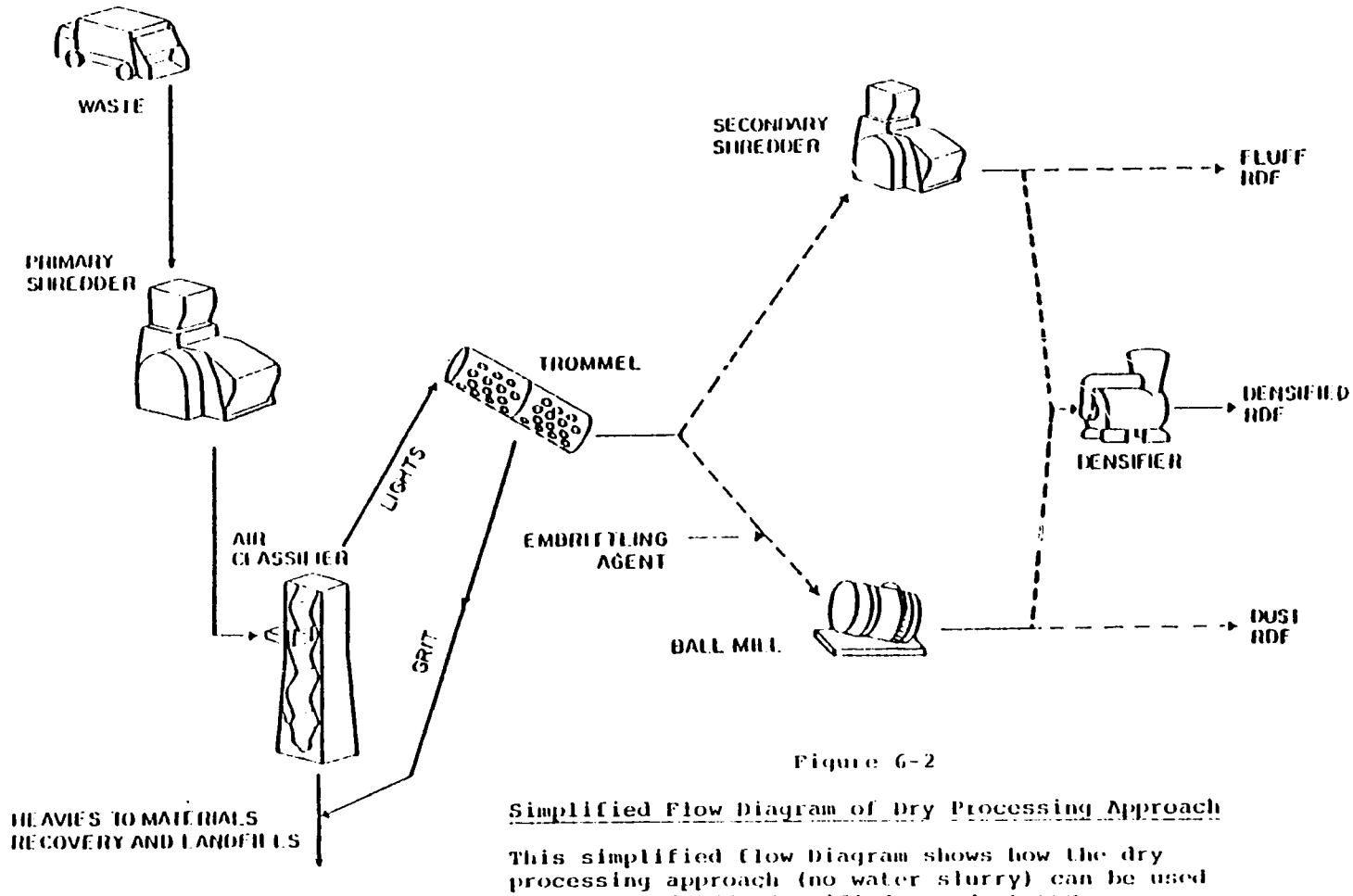


Figure 6-2

Simplified Flow Diagram of Dry Processing Approach

This simplified flow diagram shows how the dry processing approach (no water slurry) can be used to produce fluff, densified, or dust RDF

Reproduced from best available copy.

As with any materials recovery system, there must be a reliable market for the fuel. It is best if the user of the RDF has other sources of fuel and does not depend solely on RDF. Also, it is best if the fuel requirements of the customer far exceed what can be supplied by RDF. In this way the RDF serves only as a supplemental fuel. Since fluff RDF is of lower heating value than coal (5000 to 6000 Btu per pound versus 11,500 to 14,300 Btu per pound) and of higher bulk density (5 to 9 pounds per cu ft versus 42 pounds per cu ft) it is desirable not to have to transport the RDF over great distances.[5]

6.4.2.3 Pyrolysis

Pyrolysis involves the heating of organic matter in an atmosphere devoid or deficient in oxygen. The goal is the production of gaseous, liquid, or solid fuels. Temperatures of pyrolysis range from about 900°F to 2000°F. In general, the higher the temperature of pyrolysis, the higher the fraction of combustible gases produced and the lower the production of oils and chars. The pyrolysis process has been termed "destructive distillation". In its simplest form, pyrolysis may be thought of as "starved air combustion", resulting in the production of combustible gases that may be burned in an after-burner.

Gases produced in the pyrolysis of urban refuse are of low Btu value, generally ranging from 150 to 300 Btu/cubic foot, depending on the amount and source of oxygen used for partial combustion. Oils produced in pyrolysis have a heat value of about 10,000 Btu/lb. This compares with 18,000 Btu/lb for No. 6 fuel oil.[5]

Two pyrolysis systems that have been under development in the United States are shown in Figures 6-3 and 6-4.[5]

The Monsanto Landgard System, Figure 6-3, employs a controlled air primary furnace (kiln) for pyrolysis of the refuse. This is followed by an after-burner for combustion of the low heat value (120 Btu/cu ft) gas for heat recovery. The burner is arranged to provide a counter-current flow of gases and solids, thus exposing the waste to progressively higher temperatures as it passes through the kiln. The finished residue is exposed to a temperature of about 1800°F just before it is discharged from the kiln and quenched in a water-filled tank. As shown in Figure 6-3, burned gases pass through waste heat boilers where steam is generated.

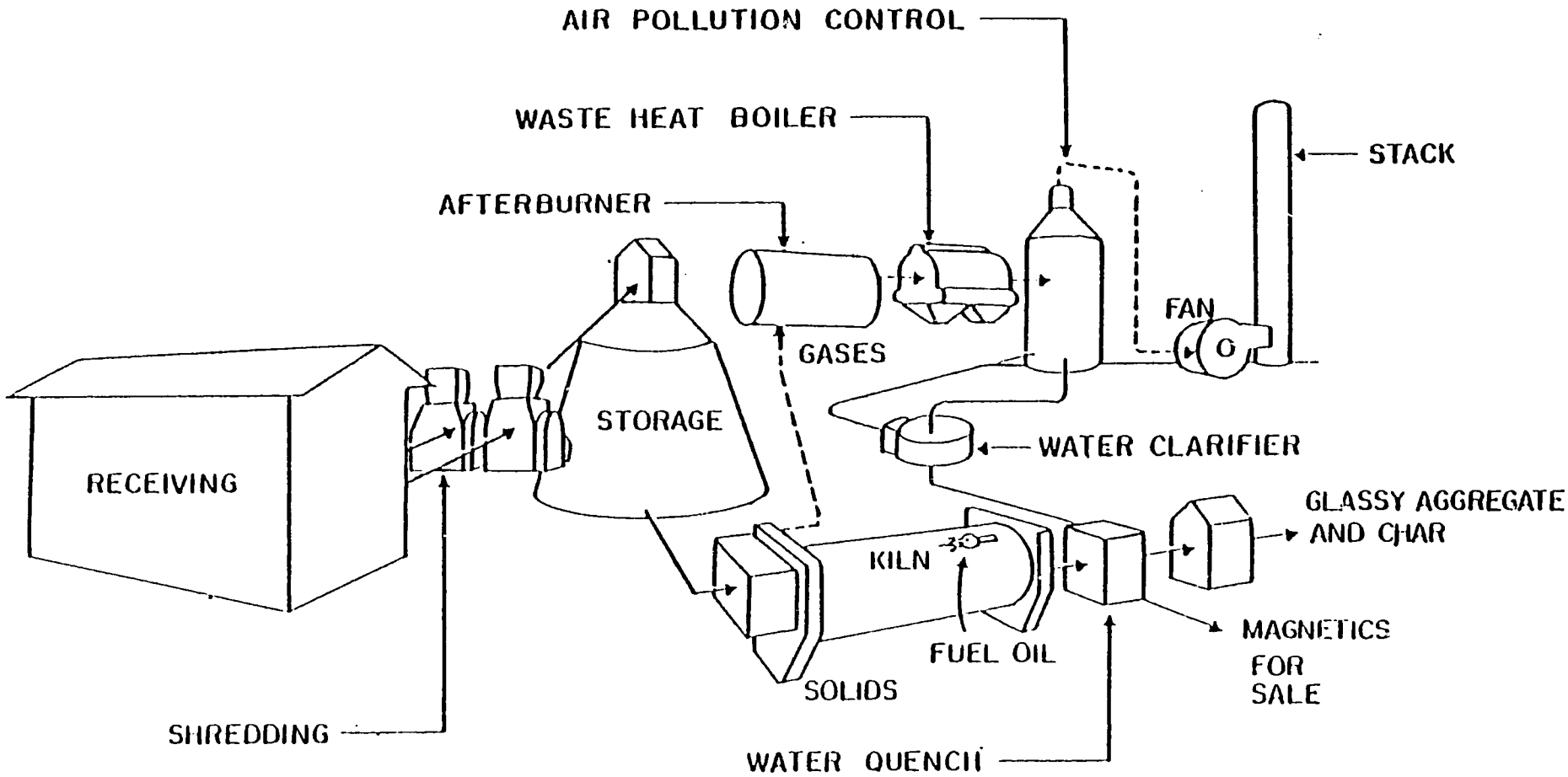


Figure 6-3

Monsanto Landguard System

The Monsanto Landgard System produces a low Btu gas which is immediately burned on-site for the production of steam.

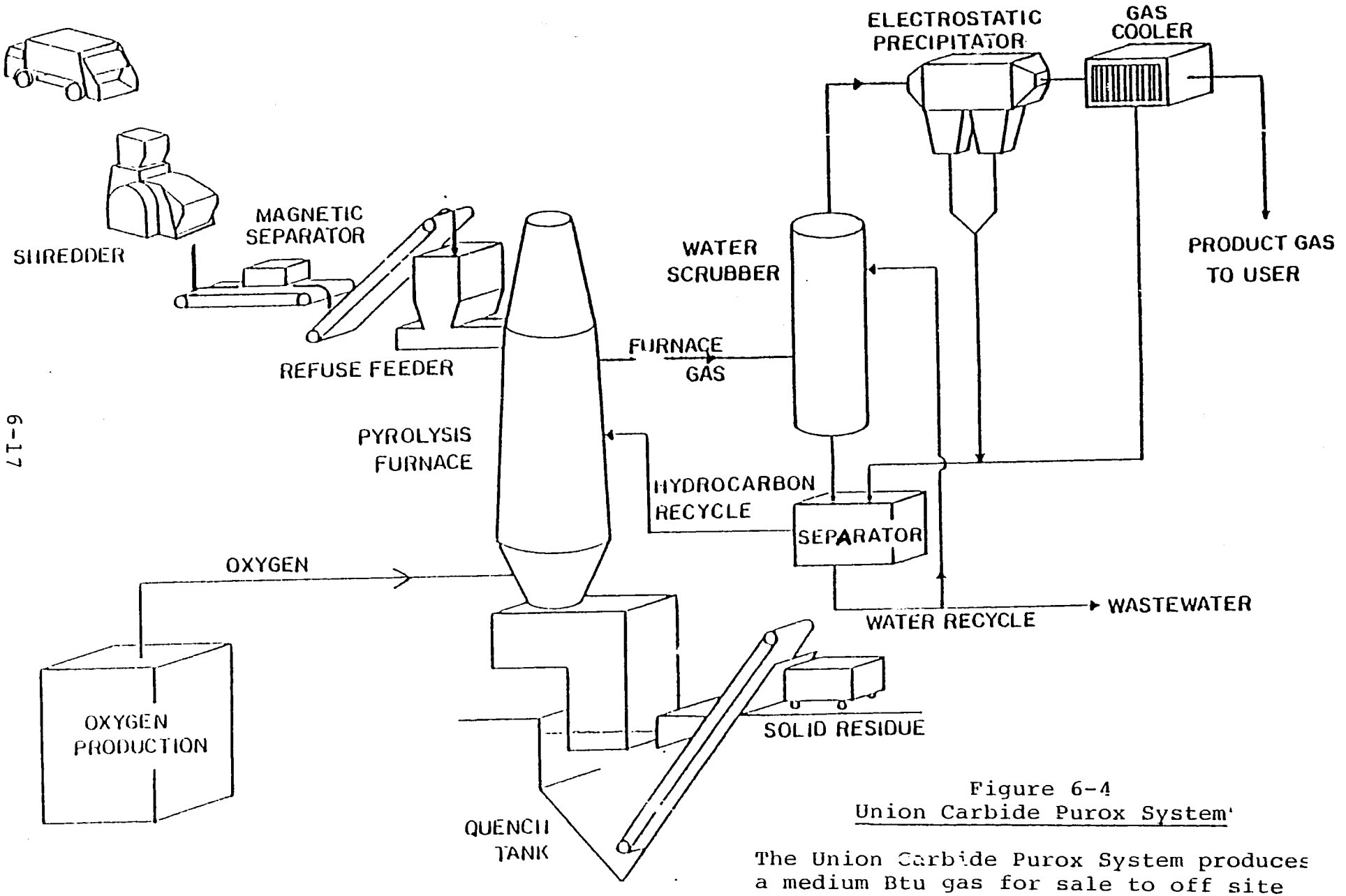


Figure 6-4
Union Carbide Purox System

The Union Carbide Purox System produces a medium Btu gas for sale to off site users

The efficiency of heat recovery from municipal solid waste for the Monsanto system is about 40 percent.[5]

A 1000 ton per day prototype of the Monsanto Landgard system has been built in Baltimore, Maryland, U.S.A. The plant has been plagued with a number of problems and, reportedly, has not achieved normal operation.[5]

The Union Carbide PUROX process (Figure 6-4) employs a vertical shaft furnace with shredded refuse fed into the top of the reactor through a piston air lock. Oxygen rather than air (as in other pyrolysis processes) is injected into the bottom of the furnace for partial oxidation of the refuse. The oxygen reacting with the char material (previously formed from refuse in the upper zone of the reactor) creates a temperature zone in the range of 3000°F in the lower portion of the reactor. Rising gases cool to approximately 200°F as they move upward, drying the incoming refuse and providing energy for pyrolyzing the incoming waste as it descends in the reactor.[5]

Gases leaving the reactor of the PUROX pyrolysis process contain considerable water vapor. This is removed in a gas cleaning step, along with ash, tars, and condensable liquids. The waste-water stream from the gas cleaning step is extremely potent with respect to its organic content (Chemical Oxygen Demand of 40,000 mg/liter or more). This waste-water cannot be discharged into the environment without treatment.[5] After cleaning, the gas from the PUROX process has a heat value of about 300 Btu/cu ft.

Union Carbide constructed a 200 ton per day PUROX pyrolysis system at South Charleston, West Virginia, U.S.A. in 1974.

As yet, the process has not been widely accepted for application to municipal urban wastes. A major problem is the treatment of the strong waste-water stream generated by the system.

Pyrolysis is a process that is well understood, but it is not a technology that has been well established for application to urban solid wastes.

6.4.2.4 Anaerobic Biological Conversion (Biogas)

The anaerobic biological conversion process is well understood and widely applied to the stabilization of sludges in the waste-water treatment field.[6,7] The stablized waste-water sludge is often applied to the land as a soil conditioner, if land is available, or the material is placed in a landfill.

A product of the anaerobic digestion process is a combustible gas. The primary components of the gas are methane and carbon dioxide. Gases present in smaller amounts include hydrogen sulfide, ammonia, and hydrogen. The gas has a heat value commonly in the range of 500 to 600 Btu per cubic foot. The gas burns well in internal combustion engines or it may be used as a fuel for boilers or other heating applications.

There are two major classes of bacteria that convert organic matter to methane (CH_4) and carbon dioxide (CO_2). The first group consists of "acid forming" bacteria that ferment the complex organics to simple intermediates, such as organic acids and alcohols. The second group of bacteria are the "methane formers". These bacteria convert the simple organics produced by the acid formers into methane and carbon dioxide.

The methane forming organisms are unique in the microbial world. They grow well in the pH range of 6.8 to 7.2, but will cease growth if the pH is much outside the range of 6.5 to 7.5. The methane formers are strictly anaerobic; therefore molecular oxygen (O_2) or ions containing oxygen (NO_3^- and $SO_4^=$, for example) are inhibitory to their growth. The organisms are slow growing, having regeneration periods of from about 4 to 10 days at 35°C. Thus the minimum solids retention time in an anaerobic digester operating at 35°C is 10 days. Anaerobic digesters designed for application to waste-water sludges commonly provide a solids retention time (SRT) of from 20 to 30 days, or more if it is thought that the units will be poorly operated or if key design parameters are uncertain.[7]

Reproduced from
best available copy.

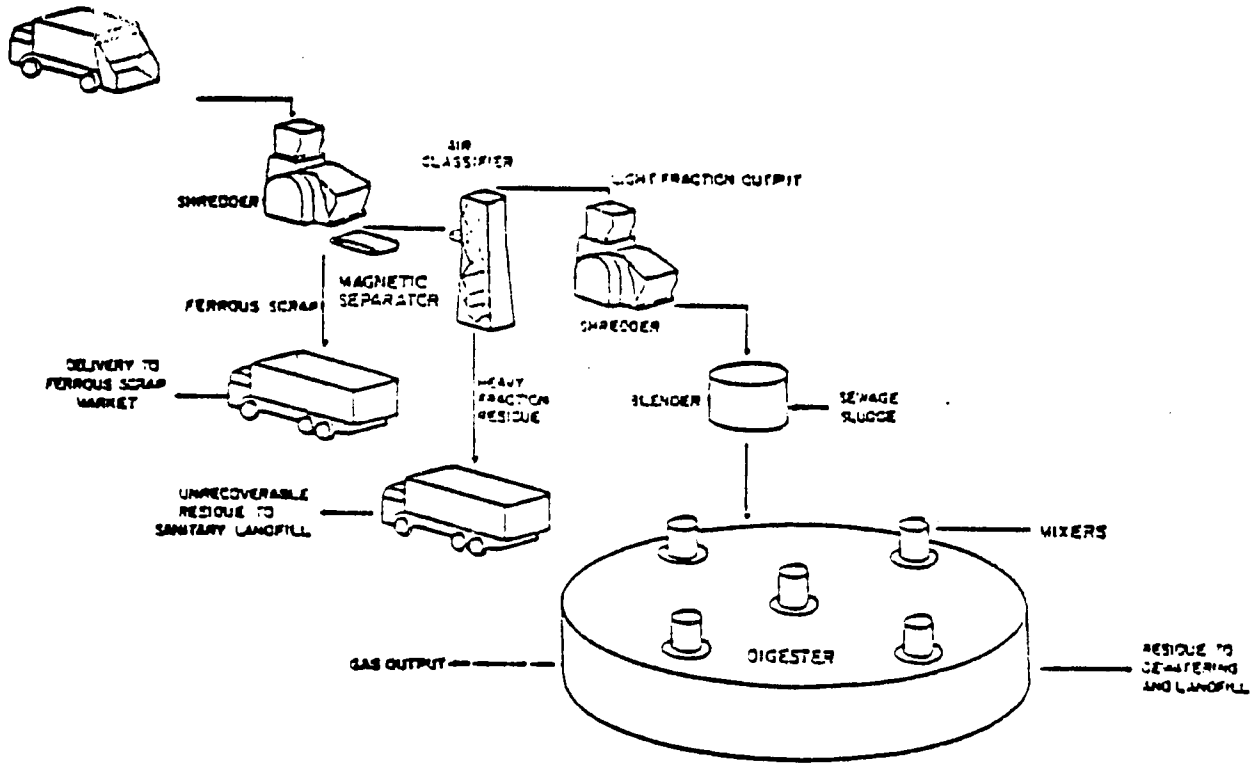


Figure 6-5 Biological Gasification of Solid Waste in Reactors

In waste-water treatment applications, the gas production from anaerobic digesters is commonly in the range of from 5 to 7 cubic feet per pound of volatile solids added to the digester. If the oxygen demand of the influent and effluent sludge streams of a digester are known, the volume of methane production can be calculated from the relationship:

$$CH_4 + 2\ O_2 = CO_2 + 2\ H_2O$$

For each pound of oxygen demand satisfied through digestion, 5.62 cubic feet of methane, at standard temperature and pressure (STP), are produced.

Over the past ten years, considerable attention has been directed toward the application of the anaerobic digestion process to municipal solid wastes for energy recovery. Laboratory and pilot scale research has been conducted by Dr. John T. Pfeffer at the University of Illinois, Urbana-Champaign, Illinois, USA. A "Proof-of-Concept" demonstration is underway at Pompano Beach, Florida, U.S.A. The 50 to 100 ton per day solid waste conversion plant is being operated by Waste Management, Inc., of Oak Brook, Illinois, U.S.A. The demonstration is sponsored by the U.S. Department of Energy.

A typical flow diagram for the anaerobic biological conversion process is shown in Figure 6-5.[5] If such a system is to operate without problems, it is essential that metals, glass, and other inerts be removed from the refuse stream prior to feeding to the anaerobic reactor. Thus a well designed and operated front end, similar to that illustrated in Figure 6-5, is vital to the system. This is a major negative aspect of the system, especially if there is no reliable market for recovered metals.

The first-stage shredder is commonly designed to reduce the incoming refuse to a 6 to 8 inch nominal size prior to the separation and classification processes. The second-stage shredder reduces the organic fraction to a 1 and 1/2 inch nominal size. This material is then blended with waste-water sludge. Ratios of solid wastes to waste-water sludge of 10 to 1 (10/1) or higher (dry weight basis) are common. The mixture is then diluted, generally using excess waste-water and recycle water from residue dewatering, to a solids

concentration in the range of 10 to 15 percent. This slurry is then fed into the reactor. Current designs call for mixing to a degree sufficient to maintain uniform conditions in the digesters and for heating to temperatures in the mesophilic ($\pm$35°C) or thermophilic ($\pm$55°C) ranges.

Research has been underway in the United States to evaluate several important aspects of the anaerobic digestion process as applied to municipal solid wastes. Key questions are:

(a) What quantity and quality of gas can be expected from the process?

(b) What reduction in organic solids can be expected as a result of the conversion to gas?

(c) What is the nature of the residue from the process and what are its dewatering characteristics?

(d) How much excess waste-water will be produced as a result of residue dewatering and what are the characteristics of this waste-water?

(e) What are the mixing requirements in the reactors?

Much of the research that has been conducted in the U.S.A. has been at temperatures of 35°C (95°F) and 60°C (140°F) and at detention times up to 30 days. The results of research by Dr. J.T. Pfeffer on gas production and composition and volatile solids destruction are given in Tables 6-1, 6-2, and 6-3.[8]

As shown in Table 6-1, a gas production of 3.05 and 4.96 cubic feet per pound of dry solids added to the digester was achieved at 95°F and 140°F, respectively, at a retention time of 30 days. At this 30 day retention time, the methane content of the gas was 53.8 and 53.7 percent at 95°F and 140°F, respectively. Volatile solids destruction was 38.0 and 61.8 percent at 95°F and 140°F, respectively.

A key question is what gas quantity and quality might be expected in applications to urban wastes in Jamaica? For purposes of evaluating the potential of biogas energy recovery from urban wastes in Jamaica, the following values are suggested:

Table 6-1. Gas Production (Cu Ft/lb Dry Solid)

Temperature (°F)	Retention Time (Days) 4	8	10	15	20	30
95.0	1.40	2.30	2.58	2.86	2.95	3.05
104.0	2.33	2.98	3.20	3.60	3.85	4.10
107.8	2.59	3.14	3.33	3.74	3.95	4.20
109.4	2.58	3.09	3.26	3.67	3.82	4.09
113.0	2.08	2.55	2.70	3.05	3.14	3.36
118.4	2.64	3.14	3.33	3.57	3.82	4.06
127.4	3.33	3.88	4.07	4.29	4.51	4.70
132.8	3.74	4.20	4.35	4.54	4.75	4.88
140.0	4.23	4.49	4.57	4.79	4.93	4.96

Table 6-2. Gas Composition at 35°C and 60°C*

35°C			60°C		
Ret. time-day	%CH_4	%CO_2	Ret. time-day	%CH_4	%CO_2
3	69.7	30.3	3	53.5	46.5
4	69.8	30.2	4	55.0	45.0
6	64.3	35.7	6	51.9	48.1
8	58.6	41.4	8	50.2	49.8
10	57.2	42.8	10	52.3	47.7
15	53.8	46.2	15	53.5	46.5
20	53.4	46.6	20	49.1	50.9
30	53.8	46.2	30	53.7	46.3

Table 6-3. Volatile Solids Destruction (per cent)*

Temperature (°F)	Retention Time (Days) 4	8	10	15	20	30
95.0	17.4	28.6	32.1	36.6	36.7	38.0
104.0	29.0	37.1	39.6	44.8	47.9	51.0
107.8	32.2	39.1	41.5	46.6	49.2	52.3
109.4	32.1	38.5	40.6	45.7	47.6	50.9
113.0	25.9	31.7	33.6	38.0	39.1	41.8
118.4	32.9	39.1	41.5	44.4	47.6	50.6
127.4	41.5	48.3	50.7	53.4	56.2	58.5
132.8	46.6	52.3	54.2	56.5	59.1	60.8
140.0	52.7	55.9	56.9	59.6	61.4	61.8

*Tables 6-1, 6-2, and 6-3 are from Pfeffer[8]

Reproduced from best available copy.

Gas production - 4.0 cubic feet (Standard Temperature and Pressure) per dry weight pound of volatile solids added to the anaerobic digester

Gas quality - 500 Btu per cubic foot of total gas produced

Volatile solids destruction - 50 percent

The dewatering characteristics of the residue from anaerobic digestion appear to be good. It would be reasonable to assume that the residue could be dewatered on vacuum filters or sand beds to a solids concentration of 25 percent.

Filtrate water from residue dewatering is rather high in pollutants. A part of this water can be recycled for slurrying the incoming refuse. Total recycle is not possible, however, due to the build-up of ions in the system that become inhibitory to the anaerobic process. For purposes of evaluation, it is reasonable to assume a 25 percent blowdown of added slurry water.

Mixing of the contents of anaerobic digesters may be accomplished by gas recirculation through diffusers located near the bottom of the reactors, or by mechanical means. As the solids concentration in the reactors increases, the power requirements for mixing increase. Tests at the solid waste conversion facility in Pompano Beach, Florida, U.S.A., indicate that a gas diffusion rate in the range of 0.8 to 1.0 standard cubic feet per minute (SCFM) per square foot of tank bottom in a 10% slurry of shredded refuse is adequate.[7] In the reactor tanks at Pompano Beach, this gas diffusion rate required an energy input of 2.8 brake horsepower (bhp) per 1000 cubic feet of reactor volume when diffusing gas at a rate of 1.0 SCFM per square foot of tank bottom.[7,9]

If mechanical mixing were used, rather than diffused methane and carbon dioxide gas, it may be possible to mix the reactor contents with a lower power input. For purposes of evaluation, a mechanical mixing requirement of 1.0 bhp per 1000 cubic foot of reactor volume is reasonable.

The technology of applying the well-known principles of anaerobic digestion to municipal solid wastes is by no means established.

6.4.2.5 Landfill with Gas Recovery

A novel approach to energy recovery from municipal refuse is the tapping of sanitary landfills to recover the combustible gases produced from the natural decomposition of organics. The concept is illustrated in Figure 6-6.[5]

The system employs a deep landfill (200 ft or more) with an impermeable bottom and final cover. Before capping, the refuse is saturated with water as it is placed. The idea is to trap the gases in the fill to be tapped by means of perforated well casings.

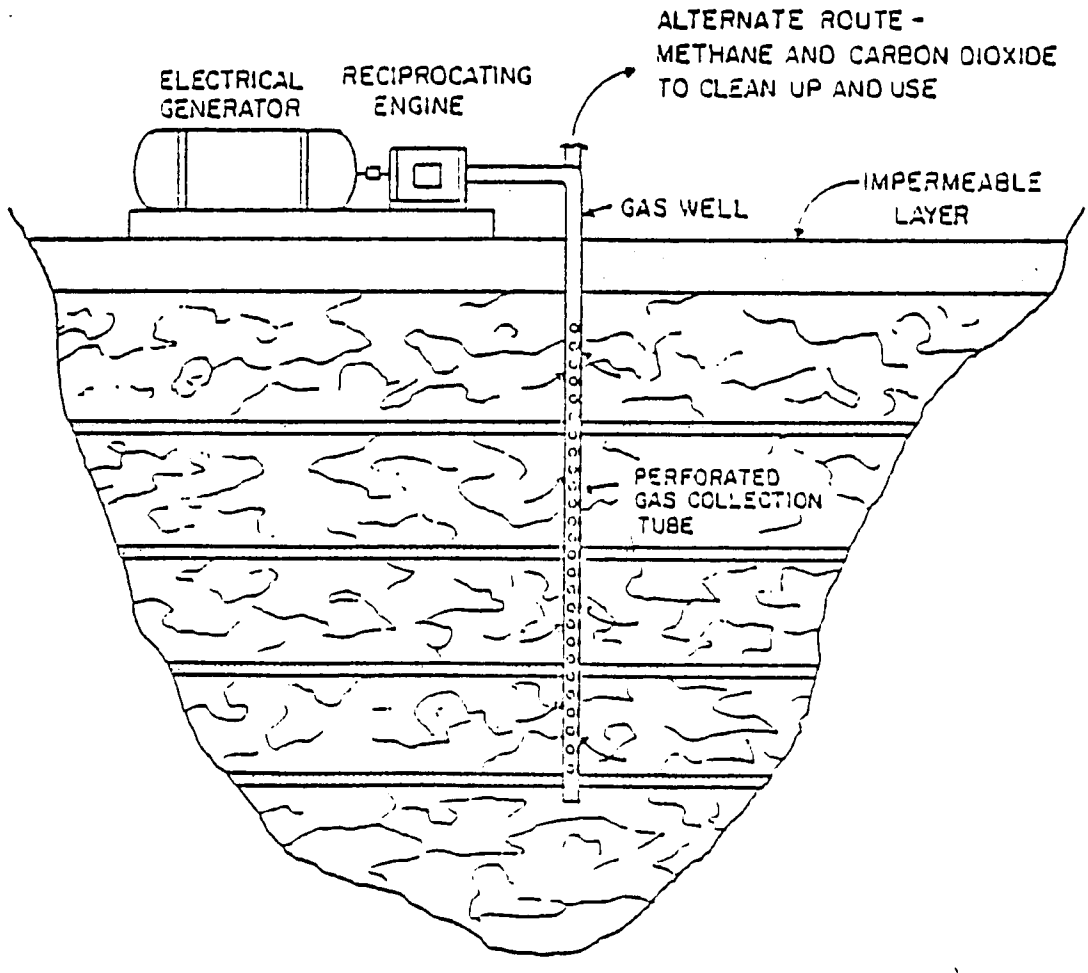


Figure 6-6 Production of Electricity from Landfill Gas

Reproduced from best available copy.

The practical utility of the landfill energy recovery approach has yet to be demonstrated. Two projects are underway to evaluate the landfill gas recovery system in the U.S.A., one at Palos Verdes and the other at Mountain View both in the State of California.[5]

Whether or not the landfill approach to energy recovery is applied to any extent in the future remains to be seen. As a practical matter, attempts to recover methane from landfills may overly complicate what is otherwise a simple method of refuse disposal.

6.4.3 Process Efficiencies

The relative efficiencies of the various energy recovery alternatives have been reported by Levy and Rigo as shown in Table 6-4.[5]

TABLE 6-4

COMPARISON OF ENERGY RECOVERY EFFICIENCIES
VARIOUS SOLID WASTE ENERGY RECOVERY PROCESSES*

Process	Net Fuel Produced	Total Amount Available as Steam
	(Expressed as percent of heat value of incoming solid waste)	
Waterwall Combustion	-	59
Fluff RDF	70	49
Dust RDF	80	63
Wet RDF	76	48
PUROX Pyrolysis	64	58
Monsanto Gasifier	79	42
Biological Gasification		
With burning of residue	29	42
Without burning residue	16	14

*From Levy and Rigo[5]

Efficiency of energy recovery, however, is not the only factor to be considered in selecting an energy and/or materials recovery approach. The following costs must also be considered: construction, management, operation and maintenance, critical spare parts, inventories, and training.

6.5 STUDY METHOD

6.5.1 Personnel Interviewed

Meetings were held with representatives of many organizations in Jamaica, including the National and local governments, officials of the University of the West Indies Mona Campus, and private individuals. Jamaican representatives having significant input to this analysis of energy recovery from urban wastes are as follows:

Ministry of Mining and Natural Resources

- Dr. Henry Lowe
- Mr. William Ashby
- Mr. A. Zia Mian
- Mr. C.J. Williams
- Mr. Daniel Barnwell

University of the West Indies, Mona Campus

- Dr. G. Lalor
- Dr. D. Radlein
- Mr. C.E. Simpson
- Mr. D. Charlie

Scientific Research Council

- Dr. K.C. Lee
- Mr. G. Williams
- Mr. A. Hales
- Dr. D. Minott
- Mr. E. Herdsman

National Planning Agency

- Dr. Omar Davis

Kingston and St. Andrews Corporation (KSAC)

- Mr. Louis Edwards

Water Commission

- Mr. Michael White
- Mr. P. Bergeron (consultant)

PetroJam

- Mr. William Saunders

Ministry of Local Government

- Mr. T. Goulbourne

Private Individuals

- Mr. K.A. Wedderburn

Another significant source of input to this study was a U.S. Energy Team seminar attended by 23 individuals with interests and knowledge in the energy recovery field. The seminar provided an effective means for exchange of thoughts, and a free discussion among the Jamaican and U.S. Energy Team participants.

6.5.2 Sites Visited

Considerable time was devoted to visiting facilities that could be involved in energy recovery efforts in Jamaica. These included:

(a) Waste-water treatment plant at the UWI, Mona Campus, and the campus areas in general

(b) Greenwich waste-water treatment plant of the Water Commission

(c) Two small biogas plants being operated by private individuals

In addition to these specific sites, a four-day, 600 mile auto trip was made around and across the island. This trip was of significant benefit in gaining a better perspective of Jamaica, its agriculture, industry, urban areas, and people.

6.5.3 Pertinent Data Reviewed

Relevant written documents and other information reviewed during the study are as follows:

(1) "Jamaica - A Case Study of Energy Planning", by Dr. Trevor A. Byer, National Resources Forum, United Nations, 1979.

(2) "Study on Solid Waste Management in the Kingston Metropolitan Region", The National Planning Agency, Kingston, Jamaica, Jan. 1979.

(3) "Metropolitan Kingston's Solid Waste - Quantity and Composition", by K.C. Lee and Rosemarie Pagon, April 1976.

(4) "Proposal on the Recovery of Methane and Electricity from Sewage and Market Garbage", by Dr. Philip Bergeron, July 1979.

(5) "Evaluation of Proposed Methane Gas Project", Jamaica Industrial Development Corporation, Feb. 1975.

(6) "Five Year Development Plan, 1978 - 1983", Government of Jamaica, Energy Sector Plan, Ministry of Mining and Natural Resources and The National Planning Agency

(7) "Urban Growth and Management Study - Final Report", National Planning Agency, Nov. 1978.

(8) "Development Plan for the Mona Campus - University of the West Indies"

(9) "Conversion of University of the West Indies Sewage Plant to a Biogas Demonstration Unit", UWI Proposal, May 1979.

6.6 FINDINGS

6.6.1 Energy Recovery Alternatives in Jamaica

Of the various alternatives discussed in Section 6.4.2, only three basic approaches are worthy of consideration in Jamaica at this time. These are:

(a) Waterwall Combustion
(b) Refuse Derived Fuel (RDF)
(c) Biological Conversion (Biogas)

Each of these approaches is capital intensive and involves the application of a reasonably high level of technology. Experience has shown that a large quantity of refuse is required before waterwall combustion or RDF approaches are cost effective. The exact quantity of daily refuse production that is necessary would not be the same in all areas of the world. The more valuable the energy or fuel, relative to the costs of recovery, the lower the quantity of refuse needed in a given case for a project to be feasible. These relative costs and values are undergoing continual change. A waste generation rate of 500 TPD or more is generally sufficient to qualify an urban area for consideration of waterwall combustion or RDF for energy or fuel recovery from urban refuse.

Application of the anaerobic biological conversion (biogas) approach on a large scale such as in Kingston is not advisable at this time. Only one facility (at Pompano Beach) has been built in the world and it has only a 50 to 100 TPD capacity. The biogas approach may have merit in the smaller communities of Jamaica.

6.6.2 Kingston Metropolitan Region

6.6.2.1 Refuse Production and Collection

A 1979 report on solid waste management in the Kingston Metropolitan Region (KMR) by consultants to the National Planning Agency is relevant to this analysis.[4] The report indicates that about 1000 tons per day (TPD) of urban solid waste is generated in the region (Kingston, St. Andrew, Spanish Town, St. Thomas, and surrounding new town developments). The population of the region was 723,700 in 1978. Somewhat over 80 percent of this population lives in the Kingston and St. Andrew Corporation (KSAC). The National Planning Agency estimates that the population of the KMR will increase to 890,000 by 1990.

The report estimated that about 80 percent of the 1000 TPD of urban refuse generated in the KMR comes from the Kingston urban area. In the KSAC area, the Public Cleansing Department (PCD) is responsible for collecting an estimated 700 TPD of refuse. Of this total, it is estimated that the PCD is able to collect only 130 TPD. The cost of collecting this 130 TPD is reported to be J. $136 per ton.[4]

The principal reasons given for the poor state of solid waste management in the KSAC are: a shortage of collection vehicles and poor maintenance of those available, an inadequate management structure, poor labor relations and a lack of status of the PCD within the KSAC. Also, there are major problems with the storage of urban wastes awaiting collection. There is considerable curbside dumping and open air burning of the dispersed refuse.[4]

The consultants estimated that the capital cost of implementing a new solid waste collection system in the KSAC and St. Catherine and St. Thomas areas would be J. $20.9 million. Annual recurring costs would be about J. $13.7 million.[4] For this analysis, it will be assumed that the capital cost for the improvement would be U.S. $12 million and annual operation and maintenance costs of U.S. $8 million.

The consultants reviewed the potential for resource recovery from the urban solid wastes. It was estimated that if the waste were used as a fuel for generating electricity, there would be a savings equivalent to 29,000 to 45,000 tons of fuel oil per year.[4] It was also mentioned that the urban wastes could be used to produce a compost for use as a soil conditioner, but compost marketability was questioned.[4]

6.6.2.2 Waterwall Combustion in Kingston

It is apparent that there are serious problems with solid waste management in the Kingston Metropolitan Region, especially in the KSAC. It is not possible to develop a successful resource recovery operation unless the waste can be collected on a reliable basis.

The 1000 TPD of urban solid wastes generated in the KMR represents a solid fuel with a heat value of 2.2×10^{12} Btu per year (at 3000 Btu per pound of refuse as collected). This is equivalent to 370,000 barrels of fuel oil per year. At U.S. $20 per barrel, this represents an annual value of U.S. $7.4 million per year.

A detailed engineering analysis and cost estimate would be required to determine whether or not revenues from the sale of refuse derived fuel (or steam) would exceed operation and maintenance costs and the cost of amortizing capital investments. If, for example, steam were produced in a waterwall furnace burning bulk refuse and if this facility required a capital investment of U.S. $40,000 per ton of daily capacity, or U.S. $40 million for a 1000 TPD plant, and if operation and maintenance costs were U.S. $10 per ton of wastes processed, annual costs would be as follows:

Annual Capital Costs (20 yrs, 8%)		$4,074,000
Annual O & M Costs ($10/ton processed)		3,650,000
TOTAL	U.S.	$7,724,000

The annual cost of collection of refuse was estimated by the previous consultants as follows:[4]

Annual Capital Costs (U.S. $12 million, 10 yrs, 8%)		$1,788,000
Annual O & M Costs		8,000,000
TOTAL	U.S.	$9,788,000

The total annual costs of efficient refuse collection with combustion in a waterwall furnace is estimated to be:

Energy Recovery Cost		$ 7,724,000
Refuse Collection Costs		9,788,000
TOTAL	U.S.	$17,512,000

With annual revenue from fuel values of U.S. $7.4 million and costs for both refuse collection and energy recovery in a waterwall furnace of U.S. $17.51 million, an annual deficit of about U.S. $10 million is indicated. By using a waterwall combustion approach, the cost of ultimate disposal of refuse in a landfill is reduced. This credit must be considered in the analysis. In addition, an efficient solid waste collection system would be of great benefit to the Kingston Metropolitan Region.

6.6.2.3 Biogas Application in Kingston

As mentioned previously, there is considerable interest in the application of the anaerobic digestion (biogas) approach to energy recovery from urban refuse.

It is interesting to calculate the size of an anaerobic digestion system that would be required to serve the KSAC. It is estimated that the quantity of refuse generated in the KSAC is 700 TPD, that the refuse is 80 percent organic, and has a moisture content averaging 50 percent (range of 30% to 65%). These data are from the recent (1979) solid waste study mentioned earlier.[4]

Based on these data, the dry weight of organic refuse produced daily in the KSAC would be 280 TPD (700 x 0.5 x 0.8 = 280). The production of a 10 percent slurry for feeding to the digesters would require the addition of 675,000 gallons of water (about 25 percent of which would be wasted daily to a treatment plant). If the digesters were sized to provide a 30 day detention time, the digestion volume would be 2,692,000 cubic feet. A total of 27 digesters, if each has a volume of 100,000 cubic feet, would be required. If the digesters were circular and had depths of 25 feet, the diameter of each unit would be 75 feet.

After digestion, 675,000 gallons of sludge, having a solids content of about 5 percent, would remain for dewatering daily. If this sludge were dewatered to 30% solids, the daily dewatered sludge production would be about 466 tons (30% solids basis).

The gas production that would be produced from the biogas facility, at 4 cubic feet of gas per pound of volatile solids added, would be about 2.24 million cubic feet per day. The Btu value of the gas (at 500 Btu/cu ft) would be 1.12 billion. This is a fuel oil equivalent of 187 barrels per day or 68,255 barrels per year.

A waterwall incineration approach applied to this same 700 TPD generated in the KSAC would result in energy, in the form of steam, equal to 421 barrels per day of fuel oil equivalent. The incineration approach is more than twice as efficient as biogas in terms of energy recovery.

6.6.3 Biogas Applications in Small Jamaican Cities

It may prove cost effective to apply the biogas approach in small cities where incineration or RDF are not feasible. This would be especially true in small communities that are constructing a new waste-water treatment plant. In such cases, the sludges from the waste-water and the organic solid wastes could be treated in a common digestion system, especially designed to handle the refuse and sludges. The economies of scale would aid in making this

system more cost effective, where such economies are not applicable in a large urban area. Also, since land is more readily available around small communities, nearby land for application of sludges would tend to be more available.

6.6.4 University of the West Indies - Mona Campus Energy Involvement

6.6.4.1 Background

As a result of current energy concerns, certain faculty and administrators at the Mona Campus of the University of the West Indies (UWI) have developed interests in helping to solve this significant national problem. The idea of the University becoming involved in an energy recovery demonstration project was proposed. The goal would be to demonstrate certain energy recovery and utilization principles to students as well as to the wider Jamaican society. It has been recognized that any given energy recovery approach may not be applicable on a large scale throughout Jamaica. Nevertheless, the demonstration could be of value in the education of students and in promoting a new "energy awareness" in Jamaican society.

The Mona Campus is served by a waste-water treatment plant having a capacity between 7.5 and 10 million gallons per month. The treatment plant consists of primary clarifiers, rock trickling filters, final clarifiers, and chlorination prior to discharge of the liquid effluent to a receiving water course. Sludges are stabilized in open, unheated, unmixed, anaerobic digestion tanks. Digested sludge is dewatered on sand drying beds. Dried sludge is used as a soil conditioner by individuals who collect and haul the material away. The plant occupies an 8 acre site. There is some space available at the treatment plant for a demonstration facility.

It is estimated that about 1000 pounds per day of refuse from the University are hauled to the treatment plant for burning in incinerators located at the site. All, or any part, of this refuse is available for use in an energy conservation demonstration.

6.6.4.2 Demonstration Alternatives

The only energy recovery alternative that is reasonably well suited to a moderately sized demonstration is anaerobic bilogical conversion. The thermal processes, incineration and pyrolysis, are not suited to small-scale applications.

6.6.4.3 Design of Biogas Demonstration Facility

One goal of the demonstration project is to produce enough fuel gas to perform some useful work. One of the smallest engines available that can also burn biogas is the Stuart engine, made in England. This engine is a single cylinder, four-cycle engine and has a power rating of 1 brake horsepower (bhp). This engine would burn about 15 cubic feet of biogas per hour or 360 cubic feet per day with continuous operation.

For the purposes of this analysis, it has been assumed that the biogas reactor would be sized to produce sufficient gas to run a 1 hp engine on a 24 hour per day basis. Thus 360 cubic feet of gas is needed daily.

The following gas quantities and characteristics have been assumed as reasonable estimates:

Gas production = 4 cubic feet Standard Temperature & Pressure (STP) per dry pound of volatile solids added to reactor

Heat value = 500 Btu per cubic foot of gas

Other assumptions in the analysis are:

a) The feed stock to the biogas reactor will be a mixture of waste-water sludge from the existing University waste-water treatment plant, refuse collected on campus, vegetation from campus trimmings, and animal wastes as available.

b) The feed stock will be shredded and inerts (glass, metals, etc.) removed prior to slurrying for feeding to the reactor.

To produce 15 cubic feet of gas per hour will require the feeding of about 3.75 lb of volatile solids per hour, or 90 lb/day, to the biogas reactor. The volume of this slurry, at 10 percent solids, would be 108 gallons/day. If the biogas reactor is sized to provide a 60 day detention time, the liquid volume of the reactor would be 6,480 gallons, or 864 cubic feet.

Gas collection and retention will also be necessary. The simplest approach is the use of a floating gas cover on the reactor.

It is assumed that the reactor would not be heated, but would operate at ambient temperatures.

It is not essential to mix the reactor contents. However, if mixing is not provided, the digesting materials will tend to segregate, resulting in floating mats, that will not digest well. It is, therefore, advisable to have some mixing. A mechanical mixer having a 0.5 hp drive would provide for mixing in the reactor.

It will also be necessary to provide sand drying beds for dewatering of the digested residue from the reactor. If a 50 percent reduction in solids occurs through digestion, the dry weight of digested solids produced daily would be 45 lb. The volume at 5 percent solids would be 108 gallons. If this slurry is dewatered on sand beds to a solids level of 25 percent, the daily weight of dewatered sludge production would be 180 lb. This material could be spread on land as a soil conditioner.

6.7 DISCUSSION OF FINDINGS

6.7.1 Urban Solid Wastes - Kingston

The major problem related to energy conversion from urban wastes in Kingston is collection. If the wastes were collected, it would be cost effective to recover energy in the form of steam in a waterwall incinerator. As shown in Section 6.6.2.2, the value as a fuel of the urban wastes generated in Kingston is about U.S. $7.4 million per year. The cost for capital and operation and maintenance of a waterwall incinerator with steam generation would be about U.S. $7.7 million per year. This analysis indicates that it would be cost effective to proceed with energy recovery from urban solid wastes in Kingston, if the wastes were being collected.

The urban solid wastes should be collected in a regular and efficient manner for the health, aesthetic, and environmental benefits involved. It is not likely that the value of the refuse as a fuel will ever increase to the point where the cost of collection can be borne from the revenues of energy recovery.

The fuel oil equivalent of the urban solid wastes generated in the Kingston Metropolitan Region is about 370,000 barrels per year. This is about 2.3 percent of the 15.751 million barrels of fuel oil equivalents used in Jamaica in 1978. This is a greater percentage of total energy consumption than is thought to be available from many other alternatives, such as solar, wind, and rural biomass conversion.

For health, environmental, and energy reasons, a careful study of urban refuse collection in Kingston should be conducted. This study should emphasize not only the physical aspects of collection (routing, scheduling, containerization, hauling, etc.) but also the management and sociological aspects of the problem. The study should evaluate in detail the quantities and characteristics of the urban refuse and alternatives and costs for energy recovery. The study should assume that energy recovery is a primary goal of developing an efficient and reliable collection system. Thus the type of recovery facility and its location would be integral parts of the study.

The cost of the feasibility study on the Kingston refuse problem should be determined after the development of detailed terms of reference and the solicitation of technical

and cost proposals from consultants. It is thought that a very good study could be conducted for a cost of U.S. $150,000.

6.7.2 University of the West Indies - Mona Campus Demonstration

In designing a facility for the purposes of a demonstration, there is always the question of how large to make the facility. Generally, the smaller the facility, the lower its cost and the simpler it is to operate. On the other hand, if the facility is too small, the purpose of the demonstration may be lost.

The volume of the proposed reactor (864 cu ft) is large enough to produce about 15 cu ft of biogas per hour, sufficient fuel for a 1 hp engine. The unit could be fed more or less biomass than the 90 lb per day dry weight mentioned in the analysis. Also, the biomass may be fed in a slurry that is thicker or thinner than the 10 percent solids assumed in the analysis. In short, the unit may be operated in a variety of modes with respect to feed rate, type of waste material, thickness of feed, detention time, etc.

It is important to recognize that a field-scale demonstration of the size and type described above, will require considerable time and effort on the part of the University of the West Indies faculty and estate management personnel. The facility will also be costly to build, operate and maintain. The cost will depend on the level of sophistication built into the system.

The probability that the anaerobic digestion process (biogas) will have significant application to urban solid wastes is very low. An important reason for this is that urban wastes are a very heterogeneous mix of materials, including not only organics but also metals, glass, plastics, rubber, and other materials not amenable to biological conversion. These inert materials must be separated from the refuse prior to feeding the organics to the bio-reactor. In addition, the biogas process is not very efficient from the standpoint of energy conversion.

The principal application of the biogas process will undoubtedly be in rural areas where animal wastes are available as a feedstock and where land is plentiful for spreading the

digested sludges on the land as a soil conditioner. Animal wastes, and to a lesser extent crop residues, are ideal for feeding to a biogas reactor. The material is generally uniform in character, high in organic content, and relatively easy to move hydrologically.

The proposed field-scale biogas demonstration at the University of the West Indies - Mona Campus would not be a very meaningful or helpful exercise in terms of proving a technology for wider use in Jamaica.

6.7.3 University of the West Indies - Mona Campus Laboratory

A better use of the available resources would be the development of a laboratory that could be devoted to research and development on a number of energy conversion alternatives, not just a single technology as would be the case in a field demonstration. This laboratory might be called an "Alternative Energies Laboratory."

It is estimated that the energy laboratory could be established and operated at a cost of U.S. $182,500 over the next three years. Details on this estimate, developed in consultation with Professor Lalor of the University, are as follows:

- Renovation of 1,000 sq ft of space @ $40/sq ft	U.S.	$ 40,000
- Salaries: One research fellow, 3 yr. @ $17,000/yr., average		51,000
- One technician, 3 yr. $5,500/yr., average		16,500
- Furnishings and Equipment		40,000
- Travel and living expenses for visiting professors to U.S. over 3 years		25,000
- Conference travel, publications etc.		10,000
Total	U.S.	$182,500

Education is an essential ingredient in developing and demonstrating the new technologies involved in energy alternatives. It is not very effective for a teacher to read about a particular technology and then to attempt to pass on the concepts to others. The teacher, especially at a university level, must be involved in a "hands on" way with what is being taught. Laboratory research provides this kind of experience and, in addition, usually results in the generation of new knowledge.

The proposed laboratory at UWI-Mona might concentrate on alternative fuels production, primarialy biomass conversion to methane (biogas) and other fermentations, such as alcohol production. The concentration in the fermentations area seems appropriate for UWI-Mona since a vary capable faculty in the areas of chemistry, microbiology and physics are located there.

It is felt to be of importance for the faculty who are to begin working in the alternative energies area to spend some time in existing research laboratories in the United States to get first-hand experience before beginning their own work. For this reason, travel funds for visiting professors are recommended.

An important use of the laboratory, of course, is education and training of students, not just research and development. The laboratory should be an extremely valuable asset for this purpose in Jamaica.

6.8 CONCLUSIONS AND RECOMMENDATIONS

6.8.1 Urban Solid Wastes - Kingston

It is concluded that the only alternative worthy of consideration for energy recovery from urban solid wastes in Kingston is waterwall incineration with steam generation. This application appears to be cost effective. The major problem is inefficient and unreliable refuse collection, making it impossible to recover energy from the wastes.

It is recommended that a detailed study of the physical, management, and sociological aspects of the collection problem in Kingston be considered.

6.8.2 University of the West Indies - Mona Campus

The results of this study lead to the conclusion that the UWI-Mona Campus should not get involved in a field-scale demonstration of the anaerobic digestion of campus refuse for methane generation.

It is recommended that the UWI-Mona Campus develop an "Alternative Energies Laboratory" and that the University be assisted financially in the amount of U.S. $182,500 over the next three (3) years.

6.9 REFERENCES

1. Byer, Trevor A., "Jamaica - A Case Study of Energy Planning." National Resources Forum, United Nations, 1979.

2. "Energy, Environment, Populations, and Food." Tuve, George L., John Wiley & Sons, New York, N.Y. (1976).

3. Five Year Development Plan (1978-83), Energy Sector Plan, Government of Jamaica.

4. Study on Solid Waste Management in the Kingston Metropolitan Region. National Planning Agency, Kingston, Jamaica (Jan. 1979).

5. Levy, S.J. and Rigo, H.G., "Resource Recovery Plant Implementation; Guides for Municipal Officials - "TECHNOLOGIES." U.S. Environmental Protection Agency, Report No. SW-157.2, Cincinnati, Ohio, USA (1976).

6. Dague, R.R., McKinney, R.E., and Pfeffer, J.T., "Solids Retention in Anaerobic Waste Treatment Systems." Journal Water Pollution Control Federation, 40, 2, Part 2, R29, Feb 1970.

7. Dague, R. R., "Application of Digestion Theory to Digester Control." Journal Water Pollution Control Federation, 40, 12, 2021, December 1968.

8. Pfeffer, J.T., "Anaerobic Processing of Organic Refuse." Proceedings of the Bioconversion Energy Research Conference, University of Massachusetts, Amherst, Mass. (June 25-26, 1973).

9. A.S.E.F. Solid Waste to Methane Gas, Waste Management, Inc., Solid Waste Reduction, Pompano Beach, Florida. Prepared for U.S. Energy Research and Development Administration, Jan. 1976.

6.10 APPENDICES

APPENDIX A - Terms of Reference

An assessment shall be made of the feasibility of constructing a prototype unit to produce energy, fertlizer and other by-products from the waste and refuse of the Mona Campus of the UWI, which has its own sewage treatment plant (50,000 gallons of water per day), refuse dumps and incinerator.

The assessment will include a determination of the amount and type of waste available on campus, a technical evaluation of alternative approaches to energy conversion from the waste, a determination of the quality of the water to be expected to be produced from the various approaches, a determination of the availability of applying the approaches to sewage and dry refuse handling in rural and urban areas of Jamaica, a recommendation as to a preferred approach and a detailed estimate of the costs of the recommended system. Personnel of the UWI should be involved in all the required activities to the maximum extent possible. The assessment will be conducted in coordination with the study of biogas described above.

APPENDIX B - Final Report Conference - Splinter Group Discussion

Before the U.S. Energy Team members left Jamaica, a Final Report Conference was held at the Jamaica Pegasus Hotel on November 13 and 14, 1979. During the first day of the conference, the U.S. Energy Team members and Jamaican counterparts presented the findings, conclusions and recommendations of each of the specialized studies. For greater exposure and increased audience participation, splinter group discussions were held during the second day. Each of the studies had a 2-3 hour question and answer session in which study parameters were reviewed and results highlighted. The following is a synopsis of the Urban Waste splinter group discussion:

Respondents: Dr. Dague - U.S. Energy Team Member
Dr. Lalor - Pro-Vice Chancellor - UWI, Mona Campus

Q.6.1. We want to use power converted from urban waste to drive a pump with a minimum 10 to 15 horsepower (hp) motor. However, you indicate that 832 cu ft of urban waste are needed to generate one (1) hp. It seems to be quite difficult to use urban waste for small-scale power conversion. Can we use the sewage treatment?

Q.6.1. Is it possible to tie in biomass conversion with urban waste?

A.6.1. (Dr. Dague) The applicability of a biogas or biomass system to urban waste is questionable. Let's analyze a small system, for example a 1000 cu ft reactor, which would require about 100 lb dry weight per day of biomass. With the assumption that dry weight is 10 percent of the total weight, we need approximately 1000 lb of urban waste per day. Before this waste goes into the reactor, it would require separation of metals and other non-reacting material. Stirring would be required. The gas generated is approximately 3 to 4 cu ft per pound (dry) of volatile matter added. In general, 1000 cu ft of urban waste can be converted into slightly more than 1 hp, but half of the power is consumed just for mixing. Therefore, not much gain is realized.

A.6.1. (Dr. Lalor) Although there is energy available in urban waste, there are two major problems in

utilizing urban waste. One is the difficulty in separating urban waste; the other is that biogas could be obtained from urban waste, but it may be neither sufficient nor efficient enough to generate more biogas. There is also another major factor, in that Jamaica's present financial situation creates difficulties in providing funds for the establishment of a garbage collection system. After examining and selecting a plan for garbage collection, we would then propose a plan for converting this urban waste into energy.

Q.6.2. Is it possible to build a community urban waste system that can hook up to the JPS (Jamaican Public Service) grid lines to supplement power?

A.6.2. (Dr. Lalor) It is possible to add generating capacity to the JPS system. Connecting small community power lines to major grid lines is very difficult. It would involve difficulties in how to feed lines to JPS and how to control the input and output capacity. Usually, the power system requires a central control system.

Q.6.3. In your report, you stated that 1000 tons per day (TPD) of garbage was collected. It would require an additional $1.7 million per year to handle this collection. However, this would save a large amount of fuel oil per year. The pay back might not be so significant, but it would save foreign exchange. Secondly, I feel that any power plant can convert from burning oil or gas to burning coal. It seems to me that we can also convert to urban waste-burning power plants. I wonder why we should not develop a garbage collection system.

A.6.3. (Dr. Dague) The garbage fuel is here. There is no need for you to import it. The energy generated from urban waste would be able to pay part of the cost, but there are other factors (social, political, etc.) to be examined, as well.

Q.6.4. Why do you have to use the waterwall generator which is so expensive?

A.6.4. (Dr. Dague) The waterwall steam generator is the most efficient (i.e., 60% efficiency) system for a power generator. The 35 to 40 million dollar estimate to build a plant was obtained through discussions with the United States

Department of Energy personnel in Washington.

Q.6.5. The possibility has been discussed to build a 5 MW plant for burning oil or coal. Have you ever calculated how many MW could be generated from urban waste per day?

A.6.5. (Dr. Dague) No, I haven't done that; my main emphasis was to work out the cost.

Q.6.6. Why is there such a big difference in your cost estimation compared to the cost projection by the British firm? Have you considered labor?

A.6.6. (Dr. Dague) A power plant requires a high quality labor force for operation. I think the cost estimation supplied by the British firm to the NPA (National Planning Agency) included the cost of collection equipment only. Their cost estimation is U.S. $12 million. Their method is to use smaller collection trucks and to divide areas into zones to solve the public health problems.

A.6.6. (Dr. Lalor) We agree that urban waste is, present, not an outstanding energy source. However, we hope that energy derived from urban waste will compensate for other costs such as social improvement, sanitation for improved public health, distribution systems, and unemployment. We know that these are not Dr. Dague's recommendations, but we should like him to put forth recommendations on social improvements and projections for the cost of urban waste compared to oil and coal in the future final report, as we want to know whether the cost comparison of urban waste and oil or coal is converging or diverging.

Q.6.7. Have you examined the waste in rural areas?

A.6.7. (Dr. Dague) Dr. Skrinde has been working on the rural agricultural application of biomass in this report. I am working on urban waste. Actually, we work together at different sites and during UWI (University of the West Indies) visits.

Q.6.8. Would you suggest that UWI only concentrate on urban waste?

A.6.8. (Dr. Dague) No, but I do suggest that this laboratory look at different areas such as the digestability of different crop residues, the amount of fertilizer value and gas value, etc. on different types of crops.

Q.6.9. There are different types of collection methods in different countries. What methods or collectors would you suggest?

A.6.9. (Dr. Dague) Referring to the liquid waste, a hydraulic system is needed to collect waste and transport it to the sewage plant. However, there is no such situation for solid waste. Jamaica is the same as other countries in the world -- the only requirement is that someone must locate the waste, load it on some type of equipment and move it to a certain area. Actually, no magic way of collection is available.

Q.6.10. What size collector would Kingston require, or is there any better method for Kingston to collect waste?

A.6.10. (Dr. Dague) There are many different sizes of refuse containers, i.e., 30, 50, 100 gallon or larger. There are also suggestions for placing lift-and-load type containers at each street corner. The problem still remains that, no matter what size or type of collectors, we need people to do the collecting. This is the difference between solid waste and sewage.

Q.6.11. I would like to mention some points for Dr. Dague to review. There are four (4) basic steps in urban waste:
1. Collection - We will have to work on collection systems for solid waste.
2. Short term measures - sanitation, energy recovery, pollution, fertilizer from solid waste.
3. The development stage of anaerobic digestion for producing gas, fertilizer, water for irrigation and pollution control from urban waste.
4. Long term development of public education on waste, optimization of energy recovery, and the beginning of the design phase.

A.6.11. (Dr. Dague) It is a complex subject and involves social aspects. Today, I read in the newspaper that Jamaica is trying to standardize all bottles. This is a very good sign. All governments (including the United States) should be standardizing containers so that only certain materials (glass or aluminum, for example) are used.

A.6.12. (Dr. Lalor) It would take many local studies to analyze the net social and energy gains in

Q.6.13. Should the university provide a training program for technical persons to prepare these studies?

A.6.13. (Dr. Lalor) The continuing study during previous and present reports should be done by the Jamaican Government. I feel that one would not want to tie down University personnel for this type of study which could be performed by other groups.

Q.6.14. Previous and present studies by consultants make recommendations for the solution to this problem. However, the problem of collection still remains. I think action must be taken towards developing collection systems.

A.6.14. (Dr. Lalor) Yes, but the University does not have any authority. With limitations on funding and assistance for technical staff, it is quite difficult to start programs.

Q.6.15. Can Jamaica provide personnel with strong engineering backgrounds to work at various research and experimental stations, or perhaps the University could provide technical stations?

A.6.15. (Dr. Lalor) That should be no problem, but the problem arises of how to pay such personnel. Moreover, we are lacking expertise and guidance.

Q.6.16. Can recommendations for solutions to this problem be part of your report?

A.6.16. (Dr. Dague) I believe it will be mentioned in the report.

Q.6.17. We know that institutional funding is limited. Perhaps we should raise local funding for development projects, but we should not concentrate on political, theoretical, etc. work -- we should concentrate on practical means.

A.6.17. (Dr. Dague) As Dr. Lalor pointed out, the research and development program must be guided by experienced faculty. Perhaps the University should initiate a visiting faculty program whereby University faculty can be exchanged with other university faculties in specific areas, so that current research programs can be compared.

A.6.17. (Dr. Lalor) This is the funding we need, as well as funds for equipment, library information and conferences. We need to identify and begin work on this problem.

Q.6.18. Can we obtain financing from international organizations to start these programs?

A.6.18. (Dr. Lalor) International organizations have provided fellowship funds for training programs. However, local people have yet to be convinced of the merits of a training program, and herein lies our internal problem.

Q.6.19. Could we begin to implement these systems in schools?

A.6.19. (Dr. Lalor) We have expended much effort in this area, but financial support is still needed because this society is looking for an approach which will prove itself to be profitable.

Q.6.20. Can students be assigned to research these problems?

A.6.20. (Dr. Lalor) Yes, but where do we obtain the financing to support the program?

Q.6.21. What is the cost of the system you mentioned?

A.6.21. (Dr. Dague) A laboratory-scale system which includes a water bath, three gas meters, glass, mixing motors, etc. would cost approximately U.S. $5000.

Q.6.22. Could we do research studies to solve this problem?

A.6.22. (Dr. Dague) The University would have to establish a research laboratory to handle the studies, i.e., the Kingston study would require much more time than that which I have spent on this study.

A.6.22. (Dr. Lalor) It is difficult to find personnel to handle this type of study. Also, there is a problem in obtaining studies that would utilize the research laboratory manpower. If we begin importing consultants to perform these studies, we would not have a chance to train local people. I would suggest waiting for the right moment.

Q.6.23. We have to collect and utilize urban wastes to be converted into energy. We have this energy source, along with the problems. Should we concentrate on this study in order to compare its benefits with the importing of coal or oil?

A.6.23 (Dr. Dague) Previous discussion focuses mainly on establishing long-term agreements for University training and research programs. However, the

Kingston study is a practical case, and it is waiting to be solved through technical, social, economic, environmental and other considerations.

Q.6.24. Would biomass systems be applicable to urban areas?

A.6.24. (Dr. Dague) Biomass systems are most applicable to rural areas and are not as suitable for large urban areas.