REPORT TO CONGRESS:

EXTENDING THE USEFUL LIFE OF SANITARY LANDFILLS AND REUSING LANDFILL AREAS

(PHASE ONE)

Office of Solid Waste
U.S. Environmental Protection Agency
March 1987

ACKNOWLEDGEMENTS

This report was prepared for the Special Wastes Branch, Office of Solid Waste, U.S. Environmental Protection Agency by two organizations. Dr. James Noble at the Center for Environmental Management, Tufts University, prepared Part One entitled Cooperative Landfill Arrangements, under an EPA grant. Part Two, Methane Production from Closed Landfills, was prepared by SCS Engineers under EPA Contract No. 68-01-7290. SCS personnel involved were Gary Mitchell and Gregory Vogt. The EPA Project Officer on both parts was Michael Flynn, and the EPA reviewers were Allen Maples and Allen Geswein.

TABLE OF CONTENTS

TABLE OF CONTENTS (cont.)

TABLE OF CONTENTS (cont.)

LIST OF EXHIBITS - COOPERATIVE LANDFILL ARRANGEMENTS

LIST OF EXHIBITS - METHANE PRODUCTION FROM CLOSED LANDFILLS

EXECUTIVE SUMMARY

The mandate for this study is found in the 1984 Hazardous and Solid Waste Amendments (HSWA) to the Resource Conservation and Recovery Act (RCRA). Under Section 702 [8002(s)], Congress directed the U.S. Environmental Protection Agency (EPA) to undertake seven studies with the common theme of extending the useful life of solid waste landfills. The text of Section 8002(s) is as follows:

> The Administrator shall conduct detailed, comprehensive studies of methods to extend the useful life of sanitary landfills and to better use sites in which filled or closed landfills are located. Such studies shall address--
>
> (1) methods to reduce the volume of materials before placement in landfills;
>
> (2) more efficient systems for depositing waste in landfills;
>
> (3) methods to enhance the rate of decomposition of solid waste in landfills, in a safe and environmentally acceptable manner;
>
> (4) methane production from closed landfill units;
>
> (5) innovative uses of closed landfill sites, including use for energy production such as solar or wind energy and use for metals recovery;
>
> (6) potential for use of sewage treatment sludge in reclaiming landfilled areas; and
>
> (7) methods to coordinate use of a landfill owned by one municipality by nearby municipalities, and to establish equitable rates for such use, taking into account the need to provide future landfill capacity to replace that so used.

This Report to Congress on Section 8002(s) will be completed in two phases. Phase I, the present report, will address Section 8002(s)(7), methods to coordinate use of a landfill owned by one municipality with nearby municipalities and Section 8002(s)(4), methane production from closed landfill units. Phase II, to be completed at a future date, will cover the remaining five areas.

The reader should be aware of several other related activities currently being undertaken by EPA. The Agency is preparing a second Report to Congress on the Subtitle D Study, which will address the adequacy of the current guidelines governing the disposal of solid waste. These guidelines, or Criteria, are entitled "Criteria for Classification of Solid Waste Disposal Facilities and Practices" (40 CFR Part 257). This report is due to Congress by November 1987. The third major effort by EPA in the solid waste disposal (or Subtitle D) area is the revising of these Criteria. EPA is required to publish final revisions by March 1988.

The present report is divided into two parts. Part One addresses Cooperative Landfill Arrangements and Part Two addresses Methane Production From Landfills.

Cooperative Landfill Arrangements (Part One)

The purpose of this part of the report is to discuss methods to coordinate use of sanitary landfills owned by one municipality with nearby municipalities. Cooperative landfill arrangements are in place in several areas of the United States and Canada. Cooperatives can extend the useful capacity of landfills and can offer savings for participating members. It is often easier to site one larger state-of-the-art landfill than several smaller landfills. Institutional difficulties can act as potential barriers to the forming of a cooperative arrangement. With the use of mediation and dispute resolution, however, these barriers can be overcome.

The process for developing a cooperative arrangement involves the following steps: development of a conceptual agreement among participants; determination of options for management of facilities; selection of landfill sites; ratification of a final arrangement; and implementation of that arrangement. A well-structured public participation program throughout this process will help ensure success of the arrangement. Strong motivation on the part of one of the municipalities is usually required in order to get the process moving to form a cooperative.

Cooperative landfill use is best coordinated through a written arrangement which specifies the roles, rights, and responsibilities of the participants. This written arrangement should address the following key issues: management, facilities, regulations, liability, operation, and cost.

The equity of costs and benefits is a prime concern for all participants in cooperative landfills because of possible uneven distribution between host and guest municipalities. Methods of compensation for the host community should be selected. Negotiation techniques provide a useful mechanism to equitably distribute these costs and benefits.

In summary, cooperative landfill arrangements are a viable option for municipalities dealing with solid waste management issues. Current experience shows that these arrangements can work and that this type of landfill use merits the active support of State and Federal governments. EPA supports the concept of cooperative arrangements as a means to achieve better landfilling practices.

Methane Production From Closed Landfills (Part Two)

At both closed and operating landfills, landfill gas (LFG) is generated as a product of the decomposition of organic matter. Landfill gas can be either a hazard or a benefit at closed and operating landfills. Hazards are associated with the explosive potential of the methane content of LFG. Some concern has been expressed about the presence of trace constituents in LFG, which may include volatile organic compounds such as benzene or toluene. These trace constituents comprise less than 1% of the LFG.

LFG generation begins almost immediately upon burial of the waste and increases rapidly with steady generation beginning within several months to a year. Relatively steady generation may continue for 10 years or longer. The rate of the LFG production is dependent on a number of site-specific factors: the age of the landfill, moisture content and distribution, and solid waste composition and quantity.

LFG generated at closed and operating landfills poses a concern for safety. LFG can migrate both horizontally and vertically below the surface and may pose an explosive danger on the surface of the landfill and nearby surroundings; fatalities and property damage have resulted from LFG explosions. Control of these gases through recovery and utilization systems or control systems can reduce the danger of explosion and may help abate odors, thus aiding in the beneficial future use of closed landfills.

Recovery of LFG for beneficial use is currently practiced at more than 50 locations nationwide with more than 40 other systems in the planning stages. The quantity, quality, and collectability of LFG, and the availability of markets are factors critical to the success of a LFG recovery project. Assuming that LFG markets are present, potential recovery sites are generally evaluated based on the following criteria: amount of refuse, refuse composition and moisture content, and age of the landfill.

The recovery of LFG is attractive because it can reduce gas-related dangers while generating revenue. LFG can be recovered and used as a replacement for or as a supplement to natural gas. Such recovery of LFG is generally limited to relatively large sites which have a nearby market for the recovered gas.

The recovery of gas via collection systems can help achieve the positive aspects of migration control, control of surface emissions, and recovery of an alternative fuel. Recovery systems withdrawing LFG can control migration and thus reduce the potential for explosions. Systems recovering LFG for energy also help control horizontal migration and surface emissions.

Regulations for LFG exist at both the Federal and State level. Federal standards establish criteria for methane concentrations in the soil at a landfill's property boundary and in structures on the site. Several States have adopted regulations concerning LFG that include gas control/migration at both operating and closed landfills. Closure requirements often address landfill gas concerns. Some States have requirements for relatively large landfills to collect or vent any LFG that is generated. Two States have regulations that encourage or require collection rather than just venting of LFG.

In most parts of the country the recovery of LFG is based almost exclusively on the value of the gas as a fuel. Where it is profitable to recover LFG, it will be recovered. The control of gas migration is related to site-specific situations and is driven by safety considerations as well.

The recovery of LFG as fuel currently rests on economics. Capital and operation and maintenance (O&M) costs for LFG recovery systems can be quite high. Thus, the right combination of site conditions, gas volumes and market conditions must be present to make recovery attractive for financial reasons only. Capital costs will always be well over $1 million; annual O&M costs are estimated to be more than 10 percent of capital costs.

As more States and possibly the Federal government, move toward additional LFG regulation, recovery will become increasingly attractive. As these regulations become more common, installation of recovery systems will become more popular for both closed and operating sites. In addition to the economic benéfits, LFG recovery will aid in meeting landfill surface emission criteria and/or help control horizontal migration. The combination of positive and negative motivators (the value of the gas as a fuel and the regulations) may result in more sites with control systems.

PART ONE

COOPERATIVE LANDFILL ARRANGEMENTS

SECTION 1

INTRODUCTION

This portion of the report addresses methods to coordinate the use of sanitary landfills owned by one municipality with nearby municipalities. The focus is the identification of major issues that may affect implementation of these municipal cooperative landfill arrangements.

Cooperative landfilling is a voluntary arrangement whereby a municipality shares its landfill space with other municipalities under a set of operating rules and compensation mechanisms. A cooperative arrangement can be financially attractive because a group of municipalities may have large enough waste volumes to achieve economies of scale in its operations.

Cooperative sanitary landfills can be generally defined as shared facilities established for the benefit of participating municipalities. The term "municipalities" includes cities and towns, counties, or other local jurisdictions. A discussion of the comparative merits of privately owned regional landfills is beyond the scope of this study.

As in the case of many other solid waste options, actual modes of implementation of cooperative landfill use may vary considerably and are site- and region-specific. A cooperative landfill can service as few as two communities. The simplest arrangement might base one cooperative landfill in one host community to serve all members. Alternatively, several communities may decide to upgrade and use their joint capacity in turn. Other more innovative uses have included bartering, in which resource-recovery facility privileges are traded for the right to dispose of residue.

The main advantages of cooperative landfill arrangements relate to potential siting flexibility, the economies of scale, and the ability to pool participating communities' resources. Appropriate landfill sites may not exist within a particular community. Because the siting of any solid waste facility is difficult, communities may find it easier to establish one, larger state-of-the-art landfill with good environmental control, rather than siting several smaller, less sophisticated facilities. In principle, the larger size of cooperative landfills and the fact that they might operate under the auspices of larger political entities may allow:

° Improved environmental compliance through state-of-the-art technology and increased accountability;

° Greater variety of funding alternatives;

° Novel means to address liability and risk;

° Improved operational controls as a result of economies of scale; and

° Improved space utilization owing to better compaction technology and the need for less daily cover material.

Increasing desire for more sophisticated management and landfill technology may well lead to the closing of many smaller, less sophisticated landfills in the following several years. Experience over the past ten years indicates a trend toward the closure of smaller sanitary landfills.

This report also addresses cooperative landfill implementation. A major impediment to such implementation is that different governmental entities may have diverse and conflicting interests and needs. Further impediments to implementaton are the apparent lack of precedents and appropriate institutional role models, and the issue of equity. These impediments can be overcome, however, through the use of dispute resolution techniques.

The issue of equity is a key component in fashioning a successful arrangement. Equity is defined as the sharing in a fair manner, of the costs and benefits among the members of the landfill arrangement. Equity relates to both host and guest municipalities. This is especially true for finance, risk and liability questions. In addition to the issue of equitable fee structures, provisions for future landfill needs of the host community is also addressed.

Part I of this report includes six major sections. Section 1 provides an introduction and Section 2 describes the rationale and background for cooperative landfill arrangements. Factors that may make cooperative landfilling attractive are reviewed and include: limited alternatives for waste disposal, reduced costs compared with operating a single-municipality landfill, history of cooperation among prospective cooperative members, and reasonable distances between participants. Economies of scale are an important motivating factor for forming cooperatives and several examples are given.

Section 2 also discusses the wide variation in prospective members and indicates that cooperative arrangements must be crafted carefully to address different interests. The current practice of cooperative landfilling is described in general terms, and examples of cooperative landfills are presented. Some potential barriers to widespread implementation of cooperative landfill arrangements are identified. The use of dispute resolution techniques, especially mediation, in overcoming these barriers is discussed.

Section 3 describes forms of a cooperative organization and outlines a method for coordinating landfill use by focusing on elements that should be addressed in a written agreement among the members. A process for developing an agreement is described, and the important role of public participation is highlighted. Elements in the written agreement include issues of management, facilities, regulations, liability, operations, and costs. Features of implementation, such as measures of performance by responsible parties, are addressed, as are techniques for accommodating changing circumstances (i.e., withdrawal or addition of participants). Various supportive activities that could be undertaken by State or local governments are identified.

Section 4 focuses on costs, which are a major motivating factor for municipalities to enter into cooperative landfill arrangements. Components of landfill costs, such as collection, transportation and disposal are enumerated. These cost factors form an important basis for allowing comparisons between cooperative landfilling and other disposal methods and for negotiating equitable rates in a cooperative arrangement.

Section 5 discusses methods for establishing equitable rates that take into account the need to provide future waste disposal capacity for participants. Several of the costs to the host municipality can be quantified and can be reflected in the tipping fee. These include landfill development and operational costs, closure and post-closure care, "disamenities" (e.g., noise, litter, and odors), loss of development potential, and road wear. Other costs include environmental and health risks, which are best addressed by liability insurance. Other costs that cannot be quantified are best addressed through negotiation or mediation between prospective members.

Section 6 contains the conclusions and recommendations for the report. The major conclusion is that cooperative landfill arrangements are a solid waste disposal option that merits consideration. These cooperative arrangements are a viable option for municipalities searching for additional landfill capacity. Cooperatives can extend the useful life of landfills through more efficient use of space. Municipalities should be encouraged to take advantage of the benefits of these cooperative landfill arrangements.

SECTION 2

RATIONALE AND BACKGROUND FOR COOPERATIVE LANDFILLS

Cooperative arrangements can offer advantages over single-municipality landfills, but such arrangements have not become common. This section describes favorable conditions for cooperative landfill development, with an emphasis on savings that can accrue from larger-scale operations. Background information is provided on a variety of types of cooperative arrangements, on current cooperative landfilling activities and on potential impediments to cooperative arrangements.

MOTIVATION FOR COOPERATIVE LANDFILL ARRANGEMENTS

Cooperative arrangements allow participating communities to share sanitary landfills according to agreed on operating rules. Such arrangements can benefit:

- Communities that have run out of landfill capacity and have no alternative available in the foreseeable future;
- Communities that have a small number of suitable landfill site candidates; and
- Communities that desire to save money by achieving economies of scale for equipment, operation and personnel.

If these basic conditions are met, three additional factors could contribute to a community's decision to consider the cooperative landfill option. While it is not necessary to have each of these conditions to establish a successful cooperative agreement, the more that are available will lead to a better chance of success. They are:

- <u>The existence of an operating landfill in at least one of the potentially interested communities.</u> This condition avoids the obstacle of siting a new facility.

- <u>A history of cooperative efforts by potential participants.</u> Experience and trust gained through the experience of cooperative efforts have proven to be important to the ten-year-old regional landfill program in Alberta, Canada.(1)

- <u>Reasonable proximity between potential cooperative landfill communities.</u> Rural communities with small landfill sites may be too remote to make cooperative arrangements economically feasible. Particularly, the increased cost of transportation could be greater than any potential savings of landfill costs.

While all of these elements are important, many describe conditions (such as lack of appropriate sites or distance between communities) over which municipal decision-makers have relatively little control. However, efforts to save money by achieving economies in landfill operation are clearly within the realm of decision-makers. The next discussion focuses on this important aspect of cooperative landfills.

ECONOMIES OF SCALE

Landfill operations are typically classified by the amount of waste they receive, with "small" being less then 200 tons per day and "large" being greater than 1,000 tons per day (2). There is a correlation between increases in waste received and increases in certain costs. Other unit costs, however, decrease as the amount of waste increases. One such economy of scale concerns daily landfill cover material. The industry rule of thumb is to estimate a 1-to-4 ratio between cover material and solid waste. (3) However, smaller landfills can use up to twice as much cover material per unit of solid waste due to their smaller daily waste accumulations. (4) There is obviously the opportunity for substantial economic savings, especially if a landfill is importing cover material from an off-site source.

Another important area in which economies of scale operate is the purchase of compacting equipment. The most efficient compactors are the least versatile machines. Therefore, a small operation will typically own a tractor that can perform a variety of functions, including site preparation, spreading cover materials and waste compaction. Larger landfills can support the cost of a specialized steel-wheeled compactor that will extend the life of the landfill by producing greater compaction rates.

Larger landfills have the potential to spread the cost of ancillary support and maintenance facilities and monitoring systems over a larger volume of waste. Support costs include: weighing refuse and collecting fees, billing, maintenance, supervision, shelters, access roads and utilities. The cost of monitoring systems and other environmental controls, such as leachate and methane gas controls, is likely to increase the minimum practical size of landfills in the future.

New landfills can plan for economies of scale by incorporating minimum solid waste flow needs into the design process and can ensure that they are achieved through cooperative arrangements, market studies, and rate structures. Existing landfills can take advantage of economies of scale by increasing the waste stream with a cooperative arrangement. The following discussion indicates the variety of cooperative arrangements that may be developed to help communities benefit from landfill sharing.

STRUCTURE OF COOPERATIVE ARRANGEMENTS

Several circumstances exist in which cooperative arrangements for landfill use between municipalities may be advantageous. An important distinguishing factor is whether a new landfill is to be established, or whether one or more existing landfills will continue in operation. In these two cases, the determination of the host community, siting issues, risk and liability issues, and a range of factors affecting choice may be quite different.

Several variations on these basic cases are possible:

- A single multi-purpose landfill may serve the solid waste disposal needs of all members of the cooperative;
- Several limited-purpose landfills (general refuse, construction/demolition wastes, trees and stumps, bulky wastes, for example) could be located in different municipalities; and
- Several general-purpose landfills could be used sequentially by cooperative members, with different members serving as "host" in turn.

Regardless of the general configuration of the cooperative, communities must address issues such as siting new facilities, expanding or modifying existing facilities, and closure of existing facilities. The negotiation processes and agreements will vary with the type, condition, and number of solid waste facilities in member communities. Given these factors, there will be considerable variation in the extent of responsibility and the role of cooperative members who will enter into a facility-siting process. Thus, some cooperative members may be required to make capital expenditures, or may be required to comply with statutory and regulatory requirements regarding facility establishment, modification, or closure. Similarly, some members must develop, maintain or expand the capability to manage and operate a landfill. The manner in which the individual members approach a cooperative venture to address equity, compensation, risk management, and liability also can vary significantly. Section 3 discusses the types of information that should be included in a written agreement among communities.

The next discussion provides information on the current practice of cooperative landfills.

CURRENT PRACTICE OF COOPERATIVE LANDFILLING

No listing of cooperative landfills operating in the United States is currently available. This report relies on publications and personal communications with State officials as data sources.

The existing literature on landfilling is dominated by publications from the mid-1970s, a period of substantial Federal funding for solid waste studies. Apparently very little information has been published on cooperative landfill use. The few papers mentioning the subject from 1973 to the present appear in U.S. EPA case studies of solid waste practices in various urban areas across the nation (5). One case study reviews solid waste management in the Detroit metropolitan area, noting an unsuccessful attempt to obtain a regional landfill arrangement (6). A case study of Fresno, California, mentions regional landfill facilities as one potential solution to an impending shortage (7). There are no recent contributions to the literature on cooperative landfill usage that could be found.

Cooperative landfills presently exist in various forms in the United States. For purposes of this study, ten States were contacted that reportedly had or planned to create cooperative landfills. Eight of these States have laws or programs encouraging the planning and implementation of cooperative landfills, but cooperatives still appear to be in the initial stages of development. These contacts provided information concerning the existence of, or plans for, cooperative landfills in each State and the potential for this type of landfill's further development.

A summary of the jurisdictional level with primary responsibility for solid waste disposal at each of the States contacted is shown in Exhibit 2-1. In the majority of States contacted, some communities have come together to form inter-municipal solid waste disposal arrangements. Two States, Delaware and New Jersey, have strong controls at the State level that are exercised at the county level.

EXHIBIT 2-1.

SOLID WASTE DISPOSAL RESPONSIBILITY
AND POLICIES FOR TEN STATES

	I	II	III	IV
Connecticut	x			x
Delaware		x	x	
Illinois	x		x	
Massachusetts	x			x
New Jersey		x	x	x
New York	x			x
Oregon	x			
Pennsylvania	x		x	x
Virginia	x			
Wisconsin	x			

I. Municipality has primary responsibility for solid waste disposal in the State.

II. State has primary responsibility for solid waste disposal, exercised through the county level.

III. State has enacted law encouraging intergovernmental solid waste disposal agreements.

IV. State has policy encouraging intergovernmental arrangements for solid waste disposal.

Case Examples

The following is a summary of cooperative landfilling efforts in the ten States contacted. Information provided here was obtained in telephone interviews with spokespersons for the State environmental protection agencies.

- Connecticut - This state has 169 municipalities. Eighty of them transport municipal solid waste to facilities outside their jurisdictions. However, many of the communities using other municipalities' facilities pay tipping fees for disposal privileges. The towns of Windsor and Bloomfield have had a cooperative arrangement since 1972. The host landfill is located in Windsor, handles about 200 tons per day, and receives no special host compensation. The cooperative does not accept waste originating in other towns.

- Delaware - A autonomous State solid waste authority has existed since 1975. It controls the State's three landfilling facilities in each of three counties: Kent, New Castle, and Sussex. The authority's control over the flow of solid waste virtually eliminates inter-county use of landfills. Each county facility serves all the municipalities within the county's jurisdiction. Each county landfill has about 20 years of remaining capacity. The regional nature of the landfills has allowed the construction of state-of-the-art facilities, in part, due to the economies of scale achieved.

- Illinois - This State passed a law in 1984 (Public Act 84-963) that greatly assists intergovernmental agreements for solid waste disposal by eliminating anti-competition issues from municipal commitment of solid waste to a disposal facility (8). The Lake County Landfill, now in the planning stages, will be an example of a landfill with cooperative features.

- Massachusetts - This State has about 170 municipal landfills. Eight of these accept municipal solid waste from beyond their own jurisdiction (9). The arrangements are generally ad hoc, resulting from the closing of an existing landfill. The proposed State solid waste plan endorses regional solid waste management, especially for combustion facilities and their ash fills.

New Jersey - New Jersey has a unique control system using the State Department of Environment Protection (DEP) and the Board of Public Utilities (BPU). The State has ninety-three public and private landfills, but eleven of them handle about 95 percent of the State's landfilled solid waste (10). The DEP directs solid waste haulers to certain districts and the BPU assigns each hauler to specific facilities. The State discourages inter-district disposal with a waste importation tax. It also encourages hosting of regional facilities with a compensation fee on each ton disposed at the facility.

- New York - This State has an ash fill planned for Nassau and Suffolk counties (Long Island) (11). The facility will be a cooperative for all the communities in those two counties. The cooperation has been enhanced with significant State resources because of the area's dependence on ground water as drinking water. The facility will have a per ton surcharge that will go to the host community.

- Oregon - The Portland Metro Council's St. John's landfill serving Clackamas, Multnomah, and Washington counties is an example of a cooperative landfill, and was started in 1932. In 1983, the Metro Council received responsibility for operations at the St. John's Landfill. Between 1983 and 1985, the landfill received several hundred tons of refuse per day from beyond the three counties in the Metro Council. Ordinance 85-194 now precludes out-of-district use of the landfill in order to extend its useful life. There is a State law imposing a 50 cent per ton fee that rewards landfill host communities.

- Pennsylvania - A recent State law encourages the transfer of solid waste disposal responsibilities from the municipal level to the county level (12). This law was created with solid waste combustion facility development in mind, but also encourages cooperative landfills. There are only a few existing county landfills, most are at the municipality level. The county facilities typically serve regions well beyond their border. Because of the tradition of home rule, however, their formation required many municipalities to work together. The Lycoming County Landfill, as an example, serves more than five counties for municipal solid waste disposal.

- Virginia - The primary example of a cooperative landfill in Virginia is the Lorton Landfill operated by the Fairfax County Public Works Department. It is a 400 acre landfill on a 3,000 acre parcel of Federally-owned land that is under the control of the District of Columbia (13). The landfill serves the District of Columbia, Fairfax County, Arlington County, the City of Alexandria, and the Alexandria Sanitation Authority, through a memorandum of understanding. The size, location, and ownership of this landfill make it unique. Other communities in Virginia, such as Norfolk, are entering into coooperative arrangements for refuse combustion facilities.

- Wisconsin - The State has about 700 licensed landfills. Five to six hundred of these are single municipality facilities. There are about 20 county level landfills in existence and another twenty to thirty in the planning stages. The county level of government is commonly relied on because individual municipalities have difficulty in siting landfills within their own borders. The county assumes liability as landfill owner and operator. Commonly, counties exclude non-county wastes to extend the useful life of the landfills. However, counties do share landfills in certain situations, such as during short-term shortages. Examples of county landfills are found in Lacross and Brown counties.

- Alberta, Canada - Cooperative landfills have been endorsed and created to eliminate open dumps (14).

The reason for forming cooperative landfills varies from case to case. In rural Massachusetts, many informal cooperative arrangements have resulted from landfill shortfalls, when existing landfills reached their capacities and no new facilities had been sited. In Long Island, New York, groups of communities are attempting to form cooperative landfills to accommodate solid waste combustion facility ash.

POTENTIAL BARRIERS TO COOPERATIVE LANDFILLING

Institutional barriers of many types may work against the formation of cooperative arrangements. Municipalities unaccustomed to working together to share services may find it easier to develop individual municipality solutions than to endure the additional approvals, negotiations, petitions, and assurances that may be required in cooperative arrangements. Models for cooperative agreements might serve as a valuable tool for communities planning or establishing a system of shared use.

Difficulty in establishing equitable rates can be a barrier and is addressed in Section 5 of this report. However, problems can occur even when services are bartered. The Massachusetts towns of Norfolk and Framingham developed a proposal in which the solid waste from Norfolk was to have been incinerated in Framingham's incinerator, in exchange for which ash would be deposited in Norfolk's landfill. The cooperative use never occurred, however, because Norfolk was concerned over the potential environmental impacts of landfilling incinerator ash.

The unsuccessful Norfolk/Framingham cooperative illustrates an important issue with respect to such arrangements: the unknowns in solid waste disposal are a public concern. Some of these unknowns could be addressed by performing additional research on the relevant environmental health issues. In other cases, deciding whether and how to share liability for a potential release of contaminants from a landfill may be a crucial prerequisite to establishing a cooperative use arrangement.

Although many States and municipalities favor regional landfilling over single-municipality landfills, few State or federal incentives for cooperatives appear to be available. Assistance in developing model programs, resolving legal issues, providing for public participation, and defraying planning costs might encourage attempts at cooperatives.

Overcoming These Barriers

Not all of these barriers are unique to cooperative landfill arrangements, and many can be overcome with additional information or assistance. One form of assistance is the use of dispute resolution techniques, especially mediation. "Mediation is a negotiation process conducted by an impartial and independent mediator or third party" (15). Through mediation:

> "... parties to a dispute meet face to face to explore the facts, issues, and various viewpoints in the dispute and seek to settle their differences through bargaining and exploring alternative solutions. If mediation is successful, the parties jointly develop a compromise agreement, a package of specified terms that each party can endorse". (16)

Although this EPA reference discusses hazardous waste facilities, information presented in the report was based on a composite of several successfully mediated disputes over the operation and siting of sanitary landfills. There are additional cases demonstrating the successful use of environmental mediation. (17, 18)

REFERENCES

1. J. Lapp, Waste Management Branch, Alberta Environment, Canada, Personal Communciation, 1986.

2. Robinson, W., ed. 1986. The Solid Waste Handbook: A Practical Guide. John Wiley & Sons, New York, New York. p. 31.

3. U.S. Environmental Protection Agency. 1976. Decision-Makers Guide on Solid Waste Management. SW-500. Washington, D.C. p. 112.

4. Kelly, M. 1986. Equipment Selection for Landfills. Waste Age (January): 72.

5. Goddard, H. 1976. Managing Solid Wastes: Economics, Technology, and Institutions. Praeger, New York, New York. pp. 237-280.

6. U.S. Environmental Protection Agency. 1973. Detroit's Municipal Solid Waste Management System. PB 236-662. Washington, D.C.

7. U.S. Environmental Protection Agency. 1973. Fresno's Solid Waste Management System. PB 234-141. Washington, D.C.

8. Stein, S. May 1986. Illinois County Prepares for Regional Waste Program. World Wastes 29 (5): 28-29.

9. Massachusetts Office of Environmental Affairs. May 29,1985. A Solid Waste Plan For Massachusetts. pp. 1-21.

10. New Jersey State Department of Environmental Protection - Division of Waste Management. May 1985. Fact Sheet: An Act Concerning Solid Waste Disposal and Resource Recovery. (A-1778) P.L. 1985, Chapter 38, Effective February 4, 1985. C.13 : 1E-136.

11. New York State Environmental Facilities Corporation. January 31, 1986. Report to the Governor and Legislature on the Long Island Regional Ashfill Project. Albany, N.Y. pp. 1-32.

12. Governor Dick Thornburgh. November, 1985. Governor Dick Thornburgh's Plan to Solve Pennsylvania's Municipal Waste Crisis. Harrisburg, Pennsylvania. pp. 1-53.

13. Metropolitan Washington Council of Governments. August, 1983. Evolution of the I-95 Resource Recovery Land Reclamation and Recreation Complex. Washington, D.C. pp. 1-53.

14. Alberta Environment. March 1985. Overview, Waste Management Assistance Program. Edmunton, Alberta. pp. 1-31.

15. U.S. Environmental Protection Agency. 1982. Using Mediation When Siting Hazardous Waste Management Facilities. SW-944. Washington, D.C. p.1.

16. Ibid.

17. Talbott, Alan R. Settling Things: Six Case Studies in Environmental Mediation. Conservation Foundation and Ford Foundation. 1983.

18. Huser, Verne C. The Crest Dispute: A Mediation Success. Institute for Environmental Mediation. Seattle, Washington. September, 1982.

SECTION 3

ESTABLISHING COOPERATIVE LANDFILL ARRANGEMENTS

This section considers the necessary ingredients in the drafting of cooperative arrangements. The negotiation process, the roles and interests of various groups, the purpose and contents of such arrangements, and matters of implementation and modification are discussed. For the purposes of this report, two terms are defined: cooperative arrangement and municipality.

A cooperative arrangement is usually a formal, binding document signed by authorized representatives of two or more municipalities which governs the use, establishment, operation and termination of a cooperative landfill and support facilities. The arrangement should do the following:

- identify the parties;
- establish all appropriate rights and duties;
- identify and describe the facilities;
- establish payment methods and schedules;
- describe operating procedures and standards (possibly referencing plans, specifications and similar documents);
- provide for modification and termination and for dispute resolution; and
- establish monitoring procedures.

"Municipality" includes any and all units of local government (including county government where it is the only unit of local government exercising general authority over an area). Where these units have executed a cooperative arrangement they are referred to as "members of the cooperative".

PROCESS FOR DEVELOPING A COOPERATIVE ARRANGEMENT

Organizing a cooperative arrangement involves the following sequential steps: development of a conceptual agreement among participants; determination of options for management of facilities; selection of landfill sites; ratification of a final arrangement; and implementation of that arrangement. Public participation programs should be an integral part of each step of the process. Legal counsel should be sought early in the process to make sure these types of arrangements are allowable in the jurisdiction. The range of complexity of each step is potentially very large. The simplest circumstance, a single municipality contracting to deposit refuse in the existing landfill of a neighbor, may raise few issues and involve few participants and a limited process. More complex arrangements involve several municipalities, substantial concerns about equity and liability, and potential significant changes in the solid waste management practices of all members. These issues may well preclude agreement unless the cooperative process is open, well-structured and participated in by all those persons having an interest in or affected by the potential arrangement.

Role of Public Participation

Public participation programs are valuable for all stages of development for a cooperative landfill arrangement, from initial site investigations to landfill post-closure care. Involving the public may:

- Increase the probability of public approval of final arrangements;

- Ensure comprehensive coverage of issues;
- Provide a forum for conflict resolution;
- Provide decision-makers with opinions and values of the community on non-quantifiable issues; and
- Increase accountability of decision-makers(1).

There are two basic types of public participation. One is limited to provision of information to the public and receiving responses; the other is based on two-way communication in which the public both perceives and has a role in decision-making.

The first type of participation is appropriate for the initial stages of site investigations for a cooperative landfill, the second type for all other activities. A lead agency should provide funding that is required to initiate public participation. There are several possible lead development agencies including a regional authority, the host community, a guest community, or a State agency.

The lack of an obvious lead agency at this crucial stage of the cooperative development process may inhibit implementation of a useful public participation program. It requires attention and commitment from the beginning.

FORMS OF ORGANIZATION

Possible multi-jurisdictional approaches to organization, with positive and negative attributes, are summarized in Exhibit 3-1. The majority of cooperative landfill arrangements are in the category of "multi-community cooperatives" (2).

One approach to a cooperative agreement has been the use

EXHIBIT 3-1.

POTENTIAL ADVANTAGES AND DISADVANTAGES OF TYPES OF MULTIJURISDICTIONAL APPROACHES*

Alternative	Potential advantages	Potential disadvantages	Conditions which favor alternative
Authority	Can finance without voter approval or regard to local debt limit Political influence minimized because board members are private citizens Autonomous from municipal budgetary and administrative constraints Can generate income to make service self-supporting Capital financing is tax exempt	Financing is complex Can become remote from public control Can compete with private industry in some areas, reducing efficiency of both	Debt ceiling prohibits financing by the municipality Voter approval of financing will delay urgent project Political activity has hindered activity in past Autonomy from municipal budgetary and administrative control would mean more efficient delivery of service
Nonprofit public corporations	Tax-exempt status Can finance without voter approval or regard to local debt limit Assets revert to community after bonds are paid	Political influence may be exerted because board members are government officials Difficult to dismantle even if better service can be provided by other sources Financing is not backed by full faith and credit of community	City wishes to shift financing requirements to an organization outside municipal bureaucracy City wishes to avoid administrative details of providing solid waste management services
Multicommunity cooperative	Tax-exempt status is available Does not require State approval	Member communities lose some autonomy Ability to raise capital depends on lead community's debt capacity and financing strength Lead community can be hurt financially unless contracts with other communities are written properly	One city is willing to take lead in securing financing
Special districts	Constituency is a distinct group of residents, not scattered bond-holders Local autonomy can be protected by having county officials serve on board	Powers limited by State statute Must rely on special tax levies requiring voter approval Creates an additional unit of government not directly elected by citizens	No other governmental unit can provide service
Governmental agreements	Flexible and enforceable method of cooperation Basic governmental structures are not changed Can be implemented quickly and easily	May be difficult to raise capital since each community must borrow No single corporate body, so all communities must agree on any decision If contracts are not carefully written, misunderstandings may arise	Service or function to be provided is not costly or complex

* SOURCE: U.S. Environmental Protection Agency, 1976. Decision-Makers Guide in Solid Waste Management. S.W.-500. U.S. Environmental Protection Agency, Washington, D.C. p. xxiv.

of a contractual mechanism. This usually requires the host community to bear ultimate responsibility and liability for the landfill and its impacts. With growing concern over liability, the host is likely to seek a form of organization that distributes liability among the users. A more complex arrangement may result, and the prospective guest municipalities may be apprehensive about potential liability. Advantages and disadvantages of each type of liability distribution should be thoroughly explored.

There are a number of regulatory, organizational and financial issues that should be addressed in the process of cooperative landfill planning. They are linked by the issue of cost savings, a primary advantage of any kind of regional facility. Cost savings can be understood only in the context of the particular organizational structure and financial methods selected for the cooperative landfill arrangement. These organizational and financial methods must be allowable within the overall legal and regulatory framework of State and local laws.

State-of-the-art landfills can require significant capital. Before deciding on an organizational structure and a method for capital financing, communities must carefully weigh the options of private or public ownership of the landfill. Advantages and disadvantages of each are summarized in Exhibit 3-2.

ELEMENTS OF A COOPERATIVE ARRANGEMENT

An arrangement should contain a number of common elements. The amount of attention that must be given to each will vary

EXHIBIT 3-2

POTENTIAL ADVANTAGES AND DISADVANTAGES OF PUBLIC AND PRIVATE OWNERSHIP AND OPERATION OF DISPOSAL FACILITIES, AND THE CONDITIONS THAT FAVOR EACH TYPE OF OPERATION*

Alternative	Potential advantages	Potential disadvantages	Conditions which favor alternative
Public	Tax-free Nonprofit Can obtain low-interest rates and/or government grants for capital-intensive systems	Community may not have expertise to operate sophisticated capital-intensive facility City may lack marketing expertise Restrictive budget policies may affect equipment replacement and maintenance	Public predisposition towards government operation of public services Creation of public jobs desired Government employees are available to operate facility
Private	Local government does not need to raise capital Often easier for private firms to buy land for a processing or disposal site Community does not bear entire risk associated with new technology	Community may have no control of fees if only privately operated facilities are available Operator may base decisions on basis of financial reward rather than community needs Legal constraints may prevent city from signing long-term contract Displacement of city employees Municipality must locate acceptable firm and negotiate contract	Borrowing power of community and/or voter approvals for bond issues needed for capital improvements in disposal facilities are limited or not available Flexibility is needed to make changes in operations that would result in labor savings and other cost reductions Desire of local government to avoid administrative details in operation of disposal facilities Community lacks sufficient technical and management expertise for efficient operation of the type of advanced system it would like to install Territorial flexibility is needed to permit operation across political boundaries, where appropriate regional agencies do not exist Commercial markets are available for recovered products Desire to bypass civil service regulations

* SOURCE: U.S. Environmental Protection Agency. 1976. Decision-Makers Guide in Solid Waste Management. SW-500. Washington, D.C. p. xxvii.

from site to site. The elements are listed below and discussed.

Management Issues

There are a wide variety of management issues relevant to cooperative arrangements. The authority, responsibility, rights, and duties of each party must be stated. The arrangement must include a management structure and procedures, and a decision-making and dispute resolution process. The governing structure of the proposed cooperative organization should respect the autonomy of the local entities.

Facilities Issues

In the cooperative arrangement, the planned or agreed-on facilities and their usage should be clearly set forth. Items that should be incorporated include:

- Description of present status and condition of site and/or facility;
- Location and description of facility(ies);
- Definition of final capacity, ultimate configuration and use of landfill site; and
- Design and specifications for landfill including expansion/modification.

Regulatory Issues

Regulations concerning landfill siting, design, construction, modification, operation and closure vary widely in the United States. They may have a major impact on the nature and form of the agreement and of the facilities. Requirements for long-term care of the landfill and protection of the environment, especially ground water, are sensitive and potentially costly items. These items should be discussed during the negotiations process and then made a part of the cooperative arrrangement. It is, therefore, essential to: (1) identify the present regulatory authorities and/or regulations and (2) to recognize that future regulatory developments may impose significant changes. Compliance with these regulations will affect landfill operation and costs. Responsibility for compliance should be specified. Since all parties should be aware of any regulatory actions affecting any of the cooperative facilities, a communication mechanism for this purpose should be established. Regular meetings with appropriate State and local officials for this and other purposes are suggested.

Though federal standards exist for solid waste disposal facilities, the principal planning, and regulatory authority rests with the States. State agencies should be consulted concerning State solid waste regulations.

<u>Liability Issues</u>

The use of solid waste management facilities creates some risk. Risks may translate into potential liabilities. Insurance can cover some but not all liabilities. Therefore, the arrangement should cover the following points:

- Insurance issues;
- Establishment of specific liability;
- Identification and allocation of responsibility for any known or potential liabilities at the onset of cooperative activities; and
- Agreement on responsibility and procedures for claims.

Operational Issues

Each party will most likely be concerned that its short and long term interests (e.g., avoidance of risk/liability, preservation of capacity, economic operation) are protected. Proper operation of the cooperative facility is necessary to meet that objective. Therefore, the arrangement should specify the principal operational requirements of each facility affected by the arrangement.

Restrictions on the receipt of certain waste streams should be addressed in the arrangement. For example, the arrangement may prohibit receipt of bulky wastes, tires, or construction debris. Daily amounts of solid waste accepted by the landfill also should be specified.

Use of facilities for other than specified wastes from members of the cooperative will continue to be a difficult issue. Of concern are matters of using up capacity presumably reserved for members, hidden revenue streams, and unauthorized types of wastes. Unless only the municipal collection vehicles of the members are to be allowed, a reasonably secure system of permits or other identification will be required.

Cost Issues

Cost issues are discussed in depth in Sections 4 and 5, but some mention is needed here. A clear delineation of costs is critical to a successful, stable arrangement. Financial arrangements for cooperative landfills relate to the size and complexity of the proposal. A wide variety of organizational and financial combinations is possible, but most of the more complex combinations are appropriate for large landfills.

The types of costs typically associated with a cooperative arrangement will include capital, operating, administrative, monitoring, and transportation/transfer expenditures. Costs may eventually be incurred for remedial action, liability and damages, closure, and long-term custody of facilities. The parties also may elect to address the issue of future waste disposal, which would include the costs of replacement facilities, to provide for those costs.

The arrangement should establish the authority and responsibility for incurring costs and for accounting. To the extent that capital costs are known, it is appropriate for the arrangement to allocate dollars; otherwise, the arrangement should establish the bases and procedures for allocation of all costs.

Exhibit 3-3 compares seven basic financial methods as to their complexity of application, ability to raise capital, cost of capital and constraints on use. Exhibit 3-4 outlines the advantages, disadvantages and favorable conditions for each method. The large number of options displayed in these exhibits emphasizes the complexity of selecting the most appropriate combination for a particular facility.

IMPLEMENTING AN ARRANGEMENT

The arrangement should include measures and procedures to assure that its terms are fairly and consistently complied with and to assess performance by each responsible party. It should establish criteria for acceptability of performance and should

EXHIBIT 3-3. CHARACTERISTICS OF CAPITAL FINANCING METHODS AVAILABLE FOR SOLID WASTE MANAGEMENT FACILITIES*

	Types of Financing		
Parameter	General obligation bonds	Municipal revenue bonds	Municipal bank loans
Complexity of application	No project information required. No project analysis required. Short lead time.	Most complex. Bond circular must contain detailed economic and technical data certified by outside consultants. Requires more time to arrange.	Less complex than bonds especially if community has bank line of credit. Very short lead time. No external advice or certification needed.
Ability to raise capital	Minimum $500,000 due to fixed transaction costs, but can combine several smaller unrelated projects. Function of community credit, not of particular project.	Minimum $1,000,000 due to heavy fixed transaction/administrative costs. In pure form, not suited for technologically risky projects. Maximum is function of protected project revenues.	No heavy fixed transaction costs makes it useful for smaller dollar needs. Maximum limited by bank lending capacity. Better than short- and medium-term loans than bond.
Cost of capital	Lowest interest rates for long-term capital. Interest cost 2-3 percent less than corporate bonds. Indirect costs include bond counsel and possibly financial consultant, but costs are relatively low.	Somewhat higher than general obligation bond. Is directly related to the probability of maintaining adequate revenue. Municipality can minimize cost of capital by giving revenue bond the risk attributes of a general obligation bond. Indirect costs higher than for general obligation loans.	Similar to general obligation bond in terms of risk and security, but affected by loan size and terms.
Constraints on use	Voter approval often required. Legal debt ceiling may exist. Can only be used by jurisdictions with taxing powers.	Can be used only for specific projects. Good only for relatively large long-term capital. Must be managed by district authority or agency. Requires stable, long-term revenue source.	Shorter loan terms than bond. Smaller dollar amounts than bond.

EXHIBIT 3-3. CHARACTERISTICS OF CAPITAL FINANCING METHODS AVAILABLE FOR SOLID WASTE MANAGEMENT FACILITIES* (continued)

Parameter	Types of Financing			
	Leasing	Current revenue capital financing	Private financing	Leveraged leasing
Complexity of application	Somewhat simple. Minimal analysis required. Very short lead time.	Least complex of municipal finance alternatives.	Problems may be locating adequate firm, negotiating contract and proposed facility site, public job reductions, other management or organizational issues. Technical and economic analysis by private firm.	Legally complex. New to public finance. May need IRS ruling in beginning; therefore, requires 6-month lead time.
Ability to raise capital	Small short-term (6-year) loans. Applicable to specific equipment, especially rolling stock.	Current revenue needed for major capital expenditures usually unavailable.	Depends on credit rating of firm and soundness of project. Firms may be limited to smaller capital than municipality with general obligation bond.	Raises 20-50% of required capital. In pure form, not for technologically risky projects. Good potential.
Cost of capital	High effective annual interest (9-18%). Same rate for public, private leases.		Higher for private firm than for municipality. Can be lowered by mechanisms like industrial revenue bond or leveraged leasing.	If city provides remaining 60-80% capital, cost lower than general obligation bond. Lessor absorbs other costs.
Constraints on use	Short term. Small dollar amounts. State-imposed restrictions on municipalities with multi-year noncancellable leases.	No legal constraints. Economic constraint on amount of available capital.	Legal constraints on long-term noncancellable contracts. Inadequate profit potential for risk. Administrative legal problems of potential mechanisms (leveraged leasing, industrial revenue bond). Current mechanisms do not benefit marginal firms.	State restrictions on city's signing of multi-year contracts. Public decision-makers unfamiliar with concept.

*Resources Planning Associates, Incorporated. Financing Methods for Solid Waste Facilities. U.S. EPA, 1974. (Distributed by National Technical Information Service, Springfield, Virginia, as PB-234-612).

EXHIBIT [illegible]4

POTENTIAL ADVANTAGES AND DISADVANTAGES OF DIFFERENT CAPITAL FINANCING METHODS, AND THE CONDITIONS THAT FAVOR EACH*

Alternative	Potential advantages	Potential disadvantages	Conditions which favor alternative
Borrowing:			
General obligation bonds	One of the most flexible and least costly public borrowing methods Requires no technical or economic analysis of particular projects to be funded Small projects may be grouped to obtain capital Least difficult to market	Requires voter approval, and elections may be expensive Must not exceed municipality's debt limit Issuing jurisdiction must have power to levy ad valorem property tax Transaction costs impose a benchmark minimum of $500,000 Capital raised becomes part of general city treasury, thus other city expenditures could draw on amount, unless specifically earmarked for solid waste Since careful project evaluation is not required, decision-makers may be unaware of technological and economic risks Ease of raising capital is a deterrent to change in existing public/private management mix, little incentive for officials to consider use of private system operators	Size of community is small or medium Voter approval likely
Municipal revenue bonds	Projected revenues guarantee payment Can be used by institutions lacking taxing power, such as regional authorities and nonprofit corporations Does not require voter approval Is not constrained by municipality's debt limitations	Effective minimum issue of $1 million, thus only useful for capital-intensive projects Information requirements of the bond circular are extensive Technical and economic analysis of project must be performed by experts outside the municipal government Cost is higher than general obligation bonds Can be used only for specific projects	Capital-intensive projects Regional facilities desired Municipality's debt limit has been reached Initiating institutions lack taxing power
Bank loans	Small-scale capital requirements for short-term funding (5 years or less) Some medium-term funding applicability since notes may be refinanced as they expire Relatively low interest cost because interest paid by municipality is tax-free to bank Source of funds on short notice No external technical or economic analysis required	Low maximum Short term Not useful for capital-intensive projects	Capital requirement is small Funds needed on short notice

(Continued)

EXHIBIT 3-4. (Continued)

POTENTIAL ADVANTAGES AND DISADVANTAGES OF DIFFERENT CAPITAL FINANCING METHODS, AND THE CONDITIONS THAT FAVOR EACH*

Alternative	Potential advantages	Potential disadvantages	Conditions which favor alternative
Bank loans (cont.)	Essentially no minimum Relatively inexpensive Voter approval generally not required No debt ceilings Can be used by institutions lacking taxing power		
Leasing	Useful as interim financing for equipment needed before appropriations or long-term capital arrangements can be made Negotiating agreement is simple and fast Only certification required is assurance of municipality's credit standing Reduces demand on municipal capital outlays since original capital raised by private corporation	Relatively high annual interest rate (9-18 percent) Amount of capital is usually limited Lease terms are generally 5 years or less Some States prohibit municipalities from entering multiyear, noncancellable contracts City will not own asset unless it purchases facility upon completion of lease period	Equipment needed before appropriations available Municipality has good credit rating
Current revenue capital financing	Least complex mechanism available No consultant or legal advice required No need for formal financial documents	No cost in the conventional sense (but higher taxes result) Communities' ability to generate surplus capital is frequently lacking Current taxpayers should not have to pay for a system that will be used far into the future Solid waste projects must compete with other municipal demands	Amount of capital necessary is small
Private financing	Municipality need not borrow capital Provides long-term flexibility for municipality	Municipality must locate acceptable firm and negotiate contract Higher cost of capital reflected in system charges There may be legal constraints which prevent signing of long-term contract Displacement of city employees	Municipality's debt limit has been reached Municipality wishes to avoid administrative details of operating solid waste facility.
Leveraged leasing	Reduces demand on municipal capital funds Interest rate on entire financial package may be lower than general obligation bonds	Legally complex City will not own asset unless it purchases facility upon completion of leasing period	

* SOURCE: U.S. Environmental Protection Agency. 1976. Decision-Makers Guide in Solid Waste Management. SW-500. U.S. Environmental Protection Agency, Washington, D.C. pp. xxii-xxiii.

include a system of sanctions or penalties and provide for their administration.

The cooperative arrangement should recognize and provide for changing circumstances. Withdrawal or addition of a participant should be addressed. Also, procedures to handle upsets in operation, such as strikes and natural disasters, should be included.

ROLES OF STATE AND FEDERAL GOVERNMENT

State and Federal governments often provide three functions: regulation, advice, and financial assistance. The principal importance of the regulatory role is that it sets conditions for landfill siting, design, and operation to ensure protection of human health and the environment. Monitoring and enforcement actions can lead to facility closure and thus provide an important stimulus to establishment of cooperative arrangements.

An advisory role could be important throughout the process of developing an arrangement. Guidance in law, technology and economics, public participation, for example, could be useful. In some cases, the State could be a party to the arrangement as a result of an enforcement action or for other reasons.

Financial assistance is a potentially powerful tool for implementing State or Federal policy in solid waste disposal. Currently, no Federal aid is available for landfill operations. The amount of aid available from States for localities varies.

RERERENCES

1. U.S. Environmental Protection Agency. April, 1981. Solid Waste Landfill Design and Operation Practices (Draft). Contract No. 68-01-3915. Washington, D.C. p. 2-2.

2. U.S. Environmental Protection Agency. 1976. Decision-Makers Guide on Solid Waste Management. SW-500. Washington, D.C. p. 10.

SECTION 4

SOLID WASTE MANAGEMENT COSTS

UNDERSTANDING TRUE COSTS

Understanding solid waste management costs, particularly landfill disposal service costs, is essential if municipalities are to evaluate cooperative landfill proposals realistically. The participation of each member in a cooperative landfill arrangement will be based on its perception of the benefits to be gained. This section provides a description of cost components that should be evaluated when considering cooperative arrangements. A municipality will not recognize the full costs of its existing landfill if costs are understated or obscured in a large category item in the municipal budget. It will underrate the real benefits of the economics of a cooperative landfill arrangement. Communities that have paid the true costs of landfill disposal are more likley to recognize the value of cooperative arrangements.

Unfortunately, the typical municipality in this country underbudgets and underaccounts the costs of its landfill disposal service. The following discussion sets out the component costs associated with landfill disposal, and is followed by a section on accounting for municipal solid waste costs.

COMPONENT COSTS OF LANDFILL DISPOSAL SERVICES

Total landfill disposal costs represent the summation of collection, transportation and disposal site costs. Collection costs are municipal-specific and vary depending on factors such as road patterns, demographics, competition, vehicle type, crew size, labor union strength, frequency and type of service and State and local regulations. In general, transportation costs are increasing as existing landfill sites become fewer and newer sites become more remote from population centers. Transportation costs also vary greatly depending on local conditions. Transportation and collection costs are closely related, and for the purposes of this discussion will be considered as one category.

Disposal site costs include all costs at a disposal site, among which are site identification, acquisition, planning, preparation, operation, closure and post-closure care. They have increased dramatically over the past 10 years. This increase is primarily due to the incorporation of improved environmental protection measures.

Increases in costs of disposal from 1975 to 1985 are illustrated in Exhibit 4-1. The largest percentage increase, nearly tenfold, was in the cost of site preparation and construction, an item that reflects the incorporation of environmental protection measures. Predevelopment cost increases reflect a more stringent siting process. The site closure and long-term care categories also reflect an increased awareness of the environmental impacts of landfills, which can continue after a facility stops receiving waste.

Overall, disposal has become more capital-intensive; therefore, total landfill disposal service costs are influenced. Changes in the mix of capital and operating costs will influence

EXHIBIT 4-1.

LANDFILL COSTS: 1975-1985

	1975[1]		1985[2]		
COST ITEM	\$/ton[3]	Percent of total cost	\$/ton[3]	Percent of total cost	Percent change from 1975 to 1985
Pre-development costs	0.25	6	1.30	9	500%
Site preparation and construction costs	0.52	12	4.90	33	960%
Site operation	3.2	76	6.50	43	200%
Site closure	0.26	6	0.70	5	270%
Long-term care	0.0	0	1.60	11	N/A
TOTAL (excluding business profit)	4.23	100	15.0	100	360%

1. Four-foot earthen liner, leachate collection system, 40-acre site, 1,000,000 tons/2,000,000 cubic yards, 15-year site life.

2. Five-foot clay liner (on-site clays), leachate collection system, 40-acre site, 1,000,000 tons/2,000,000 cubic yards, 15-year site life, 30-year long-term care period.

3. Costs are in 1985 dollars.

*Source: Gleb, R., and E. Scaro. 1985. Cost Accounting for Landfill Design and Construction Past and Present. Waste Tech '85 Proceedings, National Solid Waste Management Association, Washington, D.C.

** excluding land costs

the budgeting of municipal resources for solid waste disposal, since budgeting for capital costs requires consideration of longer-term financial options than does budgeting for operating expenses.

The relationship between the costs of transportation and onsite disposal costs is also changing. In 1976, a rule of thumb for judging the acceptability of total solid waste management costs was that for every $1 spent on disposal, $4 would be spent on transportation (1). This national average might still apply in rural areas without landfill capacity shortfalls. In urban areas experiencing shortfalls and sharp increases in disposal costs, however, this benchmark may be outdated unless transportation costs have increased proportionately. These increased transportation costs are usually due to the necessity of using even more remote facilities.

Increases in total landfill costs are occurring in an atmosphere of uncertainty regarding the future stability of those costs. Variability within the regulatory process, potential problems in obtaining environmental liability insurance, and prospective changes in the U.S. tax code all contribute to this atmosphere. Uncertainty always increases costs, because service providers need to be compensated for taking the increased risks.

COST ACCOUNTING

While the landfill costs have been increasing, the impact of the cost increases on the market is diminished by two factors:

(1) problems in accounting for the costs of solid waste disposal and (2) the lack of connection between the service provided and the fees paid to the service provider (i.e., between the service and the fees paid by the consumer). Accounting for costs of solid waste disposal is complicated by hidden and underestimated costs. Many components of solid waste disposal services are provided by governmental departments that are charged primarily with responsibilities other than solid waste disposal. These departments typically provide inspection, enforcement, legal, accounting, and payroll support to the solid waste disposal service (2). Their costs are usually not attributed directly to the function of solid waste disposal and, therefore, are hidden. In addition, tacit agreements among municipal departments often provide public institutions such as schools and hospitals with "free" disposal service. Such service is free only from the public institution's point of view; in reality, the municipality pays for the service. Municipal landfills are usually fully amortized, and municipalities may overlook many of the additional costs associated with new landfill siting when they are faced with replacing their landfill capacity.

Most revenue-generating methods for solid waste disposal services feature convenience rather than accountability. The general fund, supported primarily by property tax assessments, does not encourage accountability. It is the most common revenue source for municipal solid waste services. The advantages and disadvantages of collecting solid waste service costs through property taxes and through other methods are delineated in

EXHIBIT 4-2

POTENTIAL ADVANTAGES AND DISADVANTAGES OF TAXES AND USER CHARGES AS SOURCES OF OPERATING REVENUES AND THE CONDITIONS THAT FAVOR EACH*

Alternative	Potential advantages	Potential disadvantages	Conditions which favor alternative
Property tax	Simple to administer—no separate billing and collection system necessary If part of local property tax, it is deductible from Federal and State income taxes	Solid waste management is often a low-priority item in the budget and receives inadequate funds Costs are hidden—less incentive for efficient operation Commercial establishments pay taxes for service they may not receive	Tradition of tax financing for most public services
Sales tax	Simple to administer	Variable monthly income Requires voter approval Income may not be adequate Commercial establishments pay taxes for service they may not receive	Recreation areas with high tourist trade
Municipal utility tax	Simple to administer More equitable than ad valorem taxes Can be instituted without voter approval	Variable monthly income Income may be inadequate	Ceiling on property tax rates Tradition of tax financing for most public services
Special tax levies	Voter approval usually not required	Amount limited by statute	Ceiling on property tax rates Tradition of tax financing for most public services
User charges	Enables localities to balance the cost of providing solid waste services with revenues Citizens are aware of costs of service and can provide impetus for more efficient operations	More complex to administer Can cause problems for users on fixed incomes	Ceiling on property tax rates

* SOURCE: U.S. Environmental Protection Agency. 1976. Decision-Makers Guide in Solid Waste Management. SW-500. U.S. Environmental Protection Agency, Washington, D.C. p. xxiii.

Exhibit 4-2. All of the alternative revenue-generating methods in the exhibit, except for the user charge, indiscriminately target the general population. These methods spread the costs of providing the service over the population in a general manner, instead of on a pay-as-you-use basis. The tipping fee, on the other hand, is one mechanism used by providers of waste disposal services to collect revenues from users.

REFERENCES

1. U.S. Environmental Protection Agency. 1976. Decision-Makers Guide on Solid Waste Management. SW-500. Washington, D.C. p. 13.

2. Ibid.

SECTION 5

EQUITY ISSUES AND COMPENSATION METHODS

In cooperative landfill arrangements, the concept of equity becomes a major issue. Equity involves both fair distribution of costs among member municipalities and adequate compensation of the host municipality. Among the many considerations involved in establishing equity are host municipality costs, market considerations, future landfill capacity and waste management policies on the local, regional, State and federal levels. Future disposal capacity and liabilities for the host municipality can also form obstacles to successfully negotiating a cooperative landfill arrangement. Tipping fees should relate directly to actual landfill usage and may be used to raise revenues to pay for operating a cooperative landfill. Tipping fees and other methods are also used to compensate the host municipality. Broad equity considerations, methods of calculating tipping fees and alternative ways of providing compensation are discussed in this section.

EQUITY CONSIDERATIONS

Host Municipality

Equity for the host municipality of a cooperative landfill is critical to any negotiated agreement. It can be approached intitially by balancing the costs and benefits of any proposed arrangement. The costs include direct and external costs of the landfill, potential increases in risk and liability, and loss of future landfill capacity. Potential host municipality benefits are improvements in landfill design, operation, closure and costs which all may contribute to a decrease in future liabilities.

Host municipalities bear more of the costs associated with cooperative landfills by virtue of the presence of the landfill within their boundaries. The most common tangible costs to the host municipality are those associated with increased truck traffic, including road wear, noise, air pollution and possible traffic congestion. A less obvious cost to the host municipality during the operation and post-closure periods is the loss of potential development benefits of the acreage dedicated to the landfill. Other potential costs depend on the landfill's physical attributes, design features and operational integrity. These potential cost categories include litter; odor; aesthetics; contamination of air, surface and ground water; methane gas migration; and potential human health effects.

An additional cost to be considered is the concern of possible decrease in property value of land abutting the landfill. The incidence of decreases in land values has not been documented. In fact, a report on a closely analogous facility type, hazardous waste landfills, found both decreases and increases in property values of surrounding land parcels (1).

It is possible that many of the above host municipality costs can be significantly reduced. For example, state-of-the-art design features will reduce the potential environmental problems.

Loss of Future Capacity

A concern of a host municipality is that it will be deprived of access to disposal services in the future if it allows surrounding municipalities to use its landfill. This factor is difficult to quantify, and is even more difficult to present systematically and convincingly to skeptical members of the host municipality. As a result, the capacity issue is a common and frequently paramount barrier to attaining the prospective host municipality's acceptance of a cooperative landfill; but it can be overcome.

Future landfill capacity within a region will depend on several elements with entirely different schedules. Specifically, population growth, municipal budgets and political changes will vary within each of the area's municipalities. These changes will affect the availability of suitable landfill sites within the host municipality and guest municipalities.

Guest Municipality

A municipality in a cooperative arrangement that does not host the landfill site can be termed a "guest" municipality. Guest municipalities do not always have the ability to site a landfill in their jurisdictions. This inability will greatly influence their level of benefits from a cooperative arrangement. Clearly, the primary benefit for a guest municipality is the ability to use a nearby disposal facility. Some guest municipalities will probably incur higher transportation costs, however. The relative magnitude of all costs and benefits for host and guest municipalities will vary with local conditions. The most difficult issue usually arises in negotiating agreeable conditions with the host community.

Liability

A major difficulty affecting equity and other factors is management of the environmental and human health risks. Landfill owners and developers face substantial potential liability. The relative lack of knowledge concerning the dynamics of the solid waste decomposition process and its interaction with environmental factors such as climate, geology, groundwater, and precipitation magnifies the problem of obtaining liability insurance. The extent of responsibility for environmental damages from landfills is dependent on case-by-case circumstances.

A cooperative landfill is an alternative to a set of single-municipality landfills. Other alternatives, such as a commercial landfill, a municipal incinerator or waste-to-energy facility may also be available. Whatever the alternatives, the relative risks of each and the insurability of the risks should be factors in the decision process. Possible alternatives to traditional insurance include self-insurance by the cooperative or a larger pool of communities. Several communities or persons are required for viable self-insurance programs. Therefore, smaller landfill facilities with limited service areas may be unable to consider this option without outside assistance. State and Federal funds for insuring landfills are not currently available.

USE AND CALCULATION OF TIPPING FEE

The host municipality can incorporate the above costs with traditionally incurred costs of landfill operation and development into their tipping fee. This holds true for actual costs and perceived costs. The following list summarizes the costs that should be reflected in an equitable tipping fee:

- Landfill development and operational costs (operational costs will vary considerably depending on volume received);
- Closure costs and post-closure care;
- Disamenities for host municipality (noise, litter, odors, etc.);
- Economic losses (loss of development potential of landfill property itself, road wear, etc.); and
- Risks and uncertainties (e.g., groundwater and drinking water contamination from leachate).

The concept of equity is usually incorporated implicitly rather than explicitly because accurate data concerning the multitude of factors involved and their interactions is lacking. Incorporating these various considerations is usually accomplished via negotiation. Through negotiation, the member municipalities of a cooperative landfill can set the range of possible tipping fees for any site, determining an upper and lower bound.

The upper bound for tipping fees is usually derived from the costs of the alternative disposal services available. Calculating these costs is complicated by the wide variety of pricing systems used by alternative services (some using flat fees, some differentiating by waste composition, and others providing membership incentives) and by the different life expectancies of these alternatives. Market alternatives, even with the complexities of comparison, are the best approximations of the maximum tipping fees that could be charged by cooperative landfills considering only market conditions. The maximum fees of the market should not be seen as practical, however. It is necessary in cooperative arrangements to take into account non-market factors, such as establishing goodwill and working relationships among member municipalities, when setting actual fees. All of these factors enter into the negotiation process of fashioning an agreement that suits the participating members.

The lower bound for tipping fees usually can be defined by calculating the costs of planning, development, operation, closure, and post-closure of the landfill and distributing those costs over its projected lifetime.

In addition to the level of tipping fees, cooperative landfills need to address the structure of the fees. Fee structure, the method of ascribing fees to users, will have a large impact on the equity of the tipping fee. The simplest structure is based on a flat fee charged at the time of tipping; it is easily administered and is usually supplemented either by making a lump sum payment to the host municipality or by dedicating a portion of the tipping fee for use by the host municipality. Alternatively, fees could be assessed annually to host and member municipalities. Other fee structures could include per capita ceilings, large-volume penalties, per container charges, per volume charges, and varying charges on the basis of waste composition (e.g., bulky waste, yard waste, incinerator ash, etc.).

The complexity of tipping fee calculation rises with the number of participating municipalities. The number of alternative disposal methods available to each participating municipality will further complicate the calculation process. Host municipalities may want to establish a low tipping fee to encourage landfill use. High tipping fees might serve as an incentive for use of disposal options with more negative environmental impacts. Overall, the complexity of the fee calculation task requires thorough analysis of the implications for participating and interested communities and coordination at all levels of government. In summation, the tipping fee has important implications for the equity of the cooperative arrangement and the region's solid waste management strategy.

ALTERNATIVE METHODS OF COMPENSATION

Tipping fees are only one method of compensating host municipalities and encouraging municipalities to consider hosting cooperative landfills. Various incentives and compensation techniques for parties affected by the presence of hazardous waste management facilities have been evaluated and are presented in Exhibit 5-1. The U.S. EPA has also published a handbook which discusses compensation and incentives in siting hazardous waste managment facilities (4). Most of the concepts developed are relevant to non-hazardous waste facilities. Incentives and compensations which can be applied to sanitary landfills, are

EXHIBIT 5-1.

AN EVALUATION MATRIX OF INCENTIVE AND COMPENSATION TECHNIQUES*

Impacts by Affected Group	Improved operation and maintenance	Payments in cash	Insure adjacent property values	Increase in or prepayment of landfill prop. tax	Waste disposal service	Other services	Land and building donations to city	Monitoring of site	Establish grievance procedures	Contingency plans	Post-closure care	Low interest loans to city	Grants to city	Tax revenue payments	Industrial revenue bonds	Increase in revenue sharing
SOURCE OF FUNDS	Landfill Owner/Operator							Both Operator and State				Primarily State				
Adjacent land owners and residents																
Physical impacts																
noise, dust, litter, odor	●	•	•	0	•	●	0	●	●	•	0	0	0	0	0	0
truck traffic; deteriorating roads	●	•	0	0	•	•	0	•	●	0	0	0	0	0	0	0
Economic impacts																
decrease in property values	•	●	●	0	•	•	•	•	0	0	●	0	0	0	0	0
decline in real estate development	•	0	•	0	0	•	•	•	0	0	●	•	•	•	•	•
restricted land use options	•	•	•	0	0	0	0	•	0	0	•	0	0	0	0	0
Social impacts																
change in quality of life	•	0	•	0	•	●	●	•	•	•	•	0	0	0	0	0
loss in aesthetic value	●	0	0	0	0	•	•	•	•	0	0	0	0	0	0	0
Risks and uncertainties																
contamination of land and water	●	•	•	0	0	•	0	●	●	●	●	0	0	0	0	0
fire and explosions	●	•	•	0	0	•	0	●	•	●	•	0	0	0	0	0
health and disease related impacts	●	●	0	0	0	●	•	●	●	●	●	0	0	0	0	0
Municipal government and residents																
Physical impacts																
odor	●	0	0	0	•	•	•	●	●	0	0	0	•	0	0	0
truck traffic	●	0	0	0	●	•	•	•	●	0	0	0	•	0	0	0
Economic impacts																
decrease in potential tax revenue	0	●	0	●	0	•	•	0	0	0	•	•	●	●	●	●
Social impacts																
identification as "dumping ground"	•	•	0	•	•	●	●	•	•	0	•	0	●	•	•	•
change in community character	•	0	0	•	•	●	●	0	0	0	●	0	•	0	0	0
Risks and uncertainties																
contamination of drinking water	●	•	0	•	0	•	0	●	●	●	●	0	0	0	0	0
health and disease related impacts	●	•	0	0	0	•	0	●	●	●	●	•	●	•	•	•
long term unknown impacts	•	0	0	0	0	•	•	•	•	•	●	0	•	0	0	0

KEY: Effectiveness of each incentive at mitigating specific impact:

- ● Good
- • Fair
- 0 No effectiveness

* SOURCE: Smith, M. et al. 1985. Costs and Benefits to Local Government Due to the Presence of a Hazardous Waste Management Facility and Related Compensation Issues, Institute of Environmental Studies at the University of North Carolina, Chapel Hill, North Carolina. p.f2.

divided into three major categories:

- Preventive measures to assist the host municipality in avoiding adverse impacts (e.g., purchasing a buffer zone);
- Mitigating measures to reverse adverse impacts experienced by the host (e.g., provisions to repair roads suffering from excessive wear); and
- Compensation measures to provide the host municipality with benefits in recognition of those lost by virtue of the landfill's proximity (e.g., funding for construction of a park or a library [2]).

Each of the sixteen methods surveyed in Exhibit 5-1 has a different degree of effectiveness in mitigating impacts on the various affected parties. Improved operation and maintenance proves to be one of the most effective measures for a majority of the affected parties. This conclusion coincides with current findings that the public is more interested in reducing perceived risks through better operational procedures and design features than it is in monetary compensation.(3) It has been traditionally argued that balancing costs and benefits will convince people to accept undesirable public service facilities. This has not proven realistic in efforts to site new landfills.

The assessment of equity of any cooperative arrangement will differ with each participant. The differences will vary with local circumstances. Only after each participant recognizes its actual solid waste management costs can they evaluate whether any compensation alternative is appropriate, including tipping fees, lump sum payments, service bartering or other methods.

REFERENCES

1. Smith, M., et al. 1985. Costs and Benefits to Local Governments Due to the Presence of a Hazardous Waste Management Facility and Related Compensation Issues: Final Report. Institute for Environmental Studies, University of North Carolina, Chapel Hill, North Carolina. p. 3.

2. Massachusetts Hazardous Waste Advisory Committee, Pollution Liability Work Group. 1985. Legislative Proposal for Long-Term Solution to Unavailability of Pollution Insurance. Department of Environmental Quality Engineering, Boston, Massachusetts. p. 76.

3. Portney, K. 1984 Allaying the NIMBY Syndrome: The Potential for Compensation in Hazardous Waste Treatment Facility Siting. Hazardous Waste and Hazardous Materials 1:3.

4. U.S. Environmental Protection Agency. 1982. Using Compensations and Incentives When Siting Hazardous Waste Management Facilities. SW-942. Washington, D.C.

SECTION 6

CONCLUSIONS AND RECOMMENDATIONS

Cooperative landfill arrangements are in place in several municipalities, and other areas could benefit from landfill sharing. Cooperatives can extend the useful capacity of landfills by using space more efficiently, and members can experience net savings in waste disposal costs if the waste volume can create economies of scale.

Cooperative landfill use is best coordinated through a written agreement. However, there is great variation among municipalities, and a number of factors should be addressed.

Several conditions may exist in a community that can make cooperative landfill arrangements an attractive option for solid waste disposal. These include landfill capacity constraints, high costs of operating a single-municipality landfill, history of cooperative efforts by potential participating communities, and reasonable distances between prospective members of the cooperative.

Economies of scale may be achieved when cooperatives are formed, because the larger waste flows may allow purchase of more efficient compacting equipment and the use of less cover material for a given volume of solid waste, both of which will extend the useful capacity of the landfill. Other economies of scale may result from improved administrative procedures and more effective use of personnel.

Information in the literature on cooperative landfilling is scarce. However, there are examples of existing cooperatives and attempts at cooperatives that are instructive. Experiences in ten states have been discussed and these examples show that cooperative landfill arrangements can work.

Institutional difficulties can act as barriers to the formation of shared landfill arrangements. However, these problems can be overcome through the use of mediation and assistance to communities in the areas of planning, implementation, public participation and legal support.

The process for developing a cooperative arrangement consists of a series of sequential steps: development of a conceptual arrangement among participants; determination of options for management of facilities; selection of landfill sites; ratification of a final arrangement; and implementation of that arrangement. Throughout the process a well-structured public participation program is essential to success. The key for successful development of a cooperative arrangement is a mediation-negotiation process whereby all the prospective members meet to fashion the arrangement. As part of this mediation process, all the various roles and interests of the parties involved are discussed and resolution on these issues is reached.

There are six key issues involved in any cooperative arrangement: management, facilities, regulations, liability, operation, and cost. Management issues entail deciding on authority, responsibilities, rights, and duties of the members. A management structure and a dispute resolution process, for solving complaints after the arrangement has been formed, both need to be designed. The issue of facilities concerns the present status of all facilities involved and related capacity issues. Participating municipalities should also be familiar with applicable State and Federal regulations, as they will affect an agreement.

Liability issues must be worked out in drafting a cooperative arrangement. The most common approach is for the host community to assume the majority of the responsibility and liability of the project. Operational issues, such as daily/weekly amounts of solid waste to be accepted and possible waste restrictions should also be decided. The issues related to various costs must also be resolved.

After the major elements of the arrangement are worked out and the agreement is in place, attention is then turned toward implementation of the arrangement. A process should be designed to assure that the responsibilities of the various parties are carried out. The arrangement should also be structured to accommodate changing situations, (withdrawal or addition of members) and to plan for unforeseen events (floods, strikes, etc.)

The possible roles of State and Federal government in setting up a cooperative arrangement should be considered. Applicable regulations, technical assistance and advice, monitoring and enforcement actions, and financial assistance will impact a cooperative arrangement.

Costs are an important motivating factor in solid waste decision-making, but difficulties in landfill cost accounting may obscure the real costs of single municipality landfill operation. This factor may inhibit formation of cooperative landfills.

Cooperative landfills are pursued on the basis of their perceived benefits and efficiencies. The full efficiency of a cooperative landfill cannot be clearly seen without a delineation of present disposal costs for use in comparing proposed disposal options. Capital and operational costs will depend on local conditions and will affect the municipality's budget allocations and priorities.

Transportation costs that limit a cooperative landfill's market area will become more important in rural areas or other areas without easy access to alternative disposal facilities. Accurate accounting of a municipality's solid waste disposal costs is necessary to clarify the net benefits that accrue to the cooperative landfill alternative.

The equity of costs and benefits is a prime concern for all participants in cooperative landfills because of possible uneven distribution of these costs and benefits among host and guest municipalities. The equity of the costs and benefits is crucial in obtaining voluntary participation by all of the municipalities. Each cooperative proposal should be evaluated before selecting an appropriate strategy to achieve an equitable arrangement.

Municipalities need to evaluate other factors that affect solid waste management decisions, in addition to the cooperative landfill option. For instance, the solid waste management policies of relevant Federal and State agencies and regional authorities can significantly affect a municipality's perception of the value of various options, including cooperative landfills.

The risks and uncertainties placed on the host of a cooperative landfill have usually been covered by insurance. Insurance is a particularly useful method for municipalities to equitably share the risk of a cooperative landfill among all participants. However, the current difficulty in obtaining environmental insurance in general may inhibit development of cooperative landfill arrangements.

After establishing a need for compensation of the host municipality, the method of compensation should be selected. Differential tipping fees are a common method used at landfills and can be used as a compensation vehicle. However, lump sum payments and bartering can be used as compensation methods to accommodate particular local circumstances. Negotiation is required in order to reach equitable compensation schemes among participating municipalities.

A great deal of motivation is required to ensure the success of such a complex voluntary agreement among municipalities. One key person should be "in charge of" the effort. In some cases, this motivation is provided by circumstances facing one of the prospective members. Federal and State governments could provide incentives, in the form of technical and legal assistance, to encourage more municipalities to use landfill sharing.

Preparing a written agreement that sets out in advance the responsibilities of member municipalities with respect to liability, insurance, future solid waste disposal capacity, financial support, and other matters requires a thoughtful process. Without such agreements, however, municipalities having capacity are unlikely to share landfill space.

Cooperative landfill arrangements, whether for solid waste or for ash, are a type of landfill use that merits the active support of State and Federal governments. EPA supports the concept of cooperative arrangements as a means to achieve better landfilling practices.

PART II

METHANE PRODUCTION AT CLOSED LANDFILLS

SECTION 7

INTRODUCTION

At both closed and operating landfills, landfill gas (LFG) is generated as a product of the anaerobic decomposition of organic matter and consists of nearly equal parts of methane and carbon dioxide plus trace amounts of other gases.

LFG generated at closed and operating landfills poses a concern for safety. LFG can migrate both horizontally and vertically below the surface and may pose an explosive danger on a landfill and nearby surroundings: fatalities and property damage have resulted from LFG explosions. Control of these gases through recovery and utilization systems or control systems can reduce the danger of explosion and may help abate odors, thus aiding in the beneficial future use of closed landfills.

The Federal regulations for the control of LFG are published at 40 CFR Part 257.3-8. These regulations establish criteria for methane concentrations in the soil at a landfill's property boundary and in structures on the site.

Several states have adopted regulations concerning LFG that include gas control at both operating and closed landfills. Often, closure requirements address gas concerns, as in the State of Washington, where most relatively large landfills are now required to collect or vent LFG.

LFG can be recovered and used as a replacement for or as a supplement to natural gas. Such recovery of LFG is generally limited to relatively large sites with nearby markets for the energy. The recovery of LFG is attractive because it can reduce gas-related dangers while generating revenue. However, limited sites across the nation are viable candidates for LFG recovery, because potential sites generally must contain a minimum volume of refuse and have a market for the recovered gas. The latter sections of this report include discussions of economic factors that have an impact on gas recovery, and a decision maker's guide is also provided which describes a methodology that can be used to perform a preliminary assessment of the viability (technical and cost) of gas recovery.

SECTION 8

POTENTIAL BENEFITS AND DANGERS OF LANDFILL GAS

During the natural decomposition of organic waste in waste disposal sites, gases generated are referred to as landfill gas (LFG). LFG is composed of roughly equal quantities of methane and carbon dioxide, in addition to other trace gases. Methane is the principal gas of concern because it can be recovered and used as an alternative fuel; however, its explosive potential can pose a danger to persons, structures, and equipment on or near a disposal site.

RECOVERY AND USE

At some landfills, LFG can be recovered for beneficial use. The technical and economic viability of LFG recovery depends on size and depth of the disposal site and the presence of markets, among other factors. Recovery of LFG is similar to that for natural gas, in that wells are installed, and are connected by manifolds called header pipes. Gas is withdrawn by applying a suction to the header pipes. Before the gas is used, it usually undergoes processing that removes water and sometimes separates the methane from other constitutent gases, specifically carbon dioxide.

Landfill gas can be used in several ways. It can replace or supplement natural gas as a boiler fuel or in other combustion applications. It is frequently used as a fuel for internal combustion engines (turbines are used at very large sites) to generate electricity. LFG can also be upgraded to pipeline quality and injected into natural gas pipelines. This requires extensive processing to remove the carbon dioxide and other constituents.

In the United States, more than 50 sites recover LFG for commercial utilization (Exhibit 8-1). Exhibit 8-2 lists LFG recovery sites that are currently planned. California currently leads the list of States with the greatest number of operating commercial LFG recovery facilities. Many more projects in other parts of the country are being evaluated, designed, or have begun operation. Within the past several years, State-mandated closure regulations specific to LFG have increased landfill owners' interest in using LFG to help offset closure costs and comply with closure regulations.

The data in Exhibits 8-1 and 8-2 are summarized in Exhibit 8-3 to provide a perspective of the end use and energy production rate ranges of the 89 active and planned LFG recovery facilities. More than half (49) of these sites are generating electricity or plan to do so, but of the direct gas utilization sites, only 18 percent (7 out of 40) upgrade LFG to a high-Btu content. These figures reflect the versatility of electricity generation and the limited applicability of upgrading LFG.

The minimum size of landfill at which LFG can be profitably recovered is quite variable and highly market dependent. One of the smallest landfills at which LFG is profitably recovered is in Brattleboro, VT, which serves a residential population of about 19,000 plus associated commercial and industrial waste sources.

EXHIBIT 8-1. ACTIVE LFG RECOVERY SITES

Location - Output

CALIFORNIA

Azusa - 1.7 mcf
Corona - 5 mW
City of Industry - 0.5 mcf
Duarte - 2.3 mW
Lompoc - 0.6 mW
L.A. Bradley East - 3.0 mcf
L.A. Lopez Canyon - 2.0 mcf
L.A. Mountaingate - 4.0 mcf
Marina - 1.2 mW
Martinez (Acme) - 2.0 mcf
Menlo Park - 2.0 mW
Monterey Park - 4.0 mcf, H
Mountain View - 0.5 mcf
Mountain View (Shoreline Park) - 3.5 kW
Napa County (American Canyon) - 1.5 mW
Olinda - 5.7 mW 1 mcf
Oxnard - 15.8 mW (in phases)
Palo Alto - electricity
Palos Verdes - 1.3 mW
Penrose - 9.4 mW
Salinas - 1.4 mW
San Fernando (North Valley) - 1.1 mcf
San Jose (Newby Island) - 2.0 mW
San Leandro (Davis Street) - 3.0 mcf
Santa Barbara County (Tajiguas) - electricity
Santa Clara City - 1.4 mW
Santa Clara County (Guadalupe) - 1.5 mW
Stockton - 1 mW
Sun Valley (Sheldon-Arletta) - 1.7 mcf, H

Toyon - 9.4 mW
Upland - 0.5 mW
Whittier (Puente Hills A) - 4.0 mW
Whittier (Puente Hills B) - 0.17 mcf
Wilmington - 2.5 mcf

CONNECTICUT

Naugatuck - 0.5 mW

MARYLAND

Rockville (Gude) - 2.8 mW

MICHIGAN

Detroit ("Holloway Junior") - 1 mcf
Lansing - 130 mcf/year

MISSOURI

St. Louis - 0.2 mcf

NEW HAMPSHIRE

Manchester - 0.7 mW

NEW JERSEY

Cinnaminson - 0.5 mcf
Deptford Township - 2 mW
Dover Township - 0.4 mW

NEW YORK

Babylon - 0.5 mW
Holtsville - 0.5 mW
Huntington - 1.0 mW
Onondaga (Syracuse) - 2 mW
Riverhead - 0.5 mW
Smithtown (public) - 0.5 mW
Smithtown (private) - 1 mW
Staten Island (Fresh Kills) - 10.0 mcf, H
Yaphank - 2.0 mW

NORTH CAROLINA

High Point - 3 mcf

OREGON

Oregon City - 2 mcf, H

EXHIBIT 8-1. ACTIVE LFG RECOVERY SITES (CONT.)

FLORIDA

Pompano Beach - 3.3 mcf, H

GEORGIA

Atlanta - 3 mcf
Macon - 2 mcf

ILLINOIS

Blue Island - 4.0 mcf
Calumet City - 2.5 mcf, H
Chicago (CID) - 3.5 mcf

CANADA

Germanton - 6.6 mW
Kitchener - 0.5 mcf

PENNSYLVANIA

Lebanon - 1.2 mW
Montgomery County - 6mW
Scranton - 2 mcf, H

VERMONT

Brattleboro - 0.3 mW

WASHINGTON

Vancouver (Leichner) - 0.35 mcf

WISCONSIN

Franklin - 3.3 mW

NOTE:

Output figures, actual or estimated, are in millions of cubic feet per day (mcf) of natural gas or in megawatts (or kilowatts) of a site's electrical generation capacity. The letter "H" in the copy indicates high-Btu gas is produced by a site; all others report medium Btu output.

SOURCE: Waste Age, March 1986.

EXHIBIT 8-2. PLANNED LFG RECOVERY SITES

Location - Output

CALIFORNIA

Bonsall - 1.4 mW
Burbank - 500 kW
Fresno - 3.5 mW
Fresno (BFI) - 1 mW
Fresno County - 750 kW
Kern County (China Grade) - 1.5 mW
Orange County (Coyote Canyon) - 20 mW
Otay - 1.9 mW
Ox Mountain - 1 mW
San Jose (Singleton Road) - 1.0 mW
San Marcos - 1.9 mW
Saugas - 1.4 mW
Whittier (Puente Hills) - 40 mW
Yolo County - 2 mW
Yuba/Sutter - 1.5 mW

CONNECTICUT

New Milford - 1.2 mW
Torrington - 0.25 mW
Wallingford - 0.6 mcf

DELAWARE

Pigeon Point - 1.5 mcf

FLORIDA

Lantana/Lakeworth - gas
Pasco County - electricity

ILLINOIS

Barton - medium Btu gas

MARYLAND

Montgomery County - 2.5 mW
Prince Georges County - 1.0 mcf, 30 mW

MASSACHUSETTS

Amesbury - 2.5 mW
Worcester - 2.3 mcf

MICHIGAN

Detroit (Holloway) - 6.0 mcf, H
Riverview - 7.5 mW

NEW HAMPSHIRE

Nashua - 2.0 mW

NEW JERSEY

Kearny - 6 mcf

NEW YORK

Albany - 1.5 mcf
Bronx - electricity
Brooklyn (Fountain Ave.) - 6 mcf
Goshen - 2.5 mW
Islip - 2 mW
Merrick - electricity
Oceanside - gas, H
Oyster Bay - 2 mW
Port Washington - 1 mcf

NORTH CAROLINIA

Greensboro - 3 mcf
Winston-Salem - 0.85 mcf

OHIO

Cincinnati (Rumpke) - 6.0 mcf

EXHIBIT 8-2. PLANNED LFG RECOVERY SITES (CONT.)

OREGON

Newburg - 1.5 mW

PENNSYLVANIA

Boyerton - 1 mW
F. R. & S. - 1.3 mW
GCS (PenArgyl) - 2 mW
Helva (Whitehall) - 1.2 mW

RHODE ISLAND

Cranston - medium Btu gas
Cumberland - 0.8 mcf
Johnston (Central Landfill) - 4.5 mW

SOUTH CAROLINA

Greenville - gas

TEXAS

Ft. Worth - gas or electricity
Houston (McCarty road) - 89.0 mcf

VERMONT

Rutland - 500 kW

NOTE:

Output figures, actual or estimated, are in millions of cubic feet per day (mcf) of natural gas or in megawatts (or kilowatts) of a site's electrical generation capacity. The letter "H" in the copy indicates high-Btu gas is produced by a site; all others report medium-Btu output.

SOURCE: Waste Age, March 1986.

EXHIBIT 8-3

LFG RECOVERY SITES BY END USE AND ENERGY PRODUCTION RATE

Generation of Electricity

Active: Energy Production Rate Range (Megawatts)	No.	Planned: Energy Production Rate Range (Megawatts)	No.
0- 2	10	0- 2	13
2- 5	9	2- 5	8
5-20	5	5-40	4
Total	24	Total	25

Medium Btu Gas

Active: Energy Production Rate Range (mcf/day)	No.	Planned: Energy Production Rate Range (mcf/day)	No.
0- 2	13	0- 2	5
2- 5	9	2- 5	3
5-10	2	5-10	2
Total	23	Total	10

High Btu Gas

Active: Energy Production Rate Range (mcf/day)	No.	Planned: Energy Production Rate Range (mcf/day)	No.
0- 2	1	0- 2	1
2- 5	2	2- 5	0
5-10	1	5-10	2
Total	4	Total	3

Totals may not add to that shown on Exhibits 2-1 and 2-2 due to mixed-use facilities where no end use quantity was specified.

The site receives approximately 40 tons of refuse per day and has some 360,000 tons of refuse in place.(1) This site is far smaller than the 400 tons per day often considered to be the minimum required for profitable LFG recovery, thus illustrating the site-specific, variable nature of such projects.

MIGRATION AND EXPLOSION

Landfill gas is generated below the surface of disposal sites and tends to migrate along paths of least resistance, eventually venting into the atmosphere above the site. If a natural or man-made, relatively impermeable layer is present and overlays a relatively permeable layer, LFG can migrate laterally. Lateral migration can extend up to several thousand feet or more from a landfill and create a hazardous condition. LFG tends to accumulate in enclosed spaces such as cavities in the landfill or in basements, crawl spaces, or even rooms in structures. As a primary component of LFG, methane accumulated in such spaces poses danger because it is explosive even when it comprises as little as 5 to 15 percent of the air mixture (referred to as the lower explosive limit or LEL). When methane comprises more than 15 percent methane, the mixture is flammable. (2) Although explosions of LFG are not common, such events have damaged structures and equipment and caused injuries and fatalities. Explosions have occurred on landfills and in adjacent structures including occupied houses. Exhibit 8-4 is a tabulation of some of the damage cases attributed to LFG migration.

Migration of LFG and its explosive potential can be controlled. Numerous engineered systems can be used to prevent the migration of LFG from a disposal site or to protect individual structures. These systems often include gas monitoring facilities. Generally, gas control systems prevent migration through the use of barriers or by safely venting LFG to the atmosphere.

REGULATIONS

Federal

There are no Federal regulations for the recovery and use of LFG. The Environmental Protection Agency has published the Criteria for Classification of Solid Waste Disposal Facilities and Practices at 40 CFR Part 257.3. These criteria essentially define a sanitary landfill, but are neither binding on the States nor Federally enforceable. Explosive gases (methane) are addressed in 40 CFR 257.3-8, which specifies that methane is not to be present in the soil at the property boundary above its LEL, nor is it to be above 25 percent of the LEL in any site structure.

State

Several states have adopted regulations that address LFG control at both operating and closed landfills. In many states, closure requirements often address gas concerns.

States with LFG regulations include Florida, Pennsylvania, California, and Washington. Florida has closure plan regulations requiring sanitary landfills to conduct a gas migration investigation. This investigation must include monitoring of test points along the property boundary and within on-site structures.

EXHIBIT 8-4

LANDFILL GAS MIGRATION DAMAGE CASES

Landfill Name, Location, and Date	Methane Detected Off-Site Above LEL?/ Distance*	Explosion/ Fire?**	Landfill Characteristics And Corrective Action+	Damages and Other Comments	Data Sources
Bakersfield Landfill Fresno,CA. April 1984	Yes/N/A	Yes On-Site	Control system installed after incident.	Fresno police bomb squad used site for practice A bomb was buried and was detonated causing LFG explosion. Explosive levels of methane were migrating off-site	1
Operating Industries Landfill Monterey Park, CA August 1983	Yes/No information available	No	Class 1 landfill LFG recovery system present Control system existed prior to incident.	Vinyl chloride detection casued SCAQMD to order 30-day shutdown of land-fill. It reopened, subject to closure in six-months.	1
BKK Landfill West Covina, CA August-October 1984	Yes/250	Yes	Class 1 Landfill Control System expanded after incident.	Twenty residences temporarily evacuated due to explosive methane levels in adjoining soils.	1, 2
Wallingford Landfill Wallingford, CT June 1984	Yes/No information available	No	LFG recovery system present.	Explosive levels of methane detected in dog pound. Dog pound temporarily closed, ventilation system to be installed.	1, 2
Shawnee County Landfill Topeka, KA August 1983	Yes/No information available	No	No information available	Home abandoned due to high methane levels.	1

Symbols

N/A Not applicable

* Reported distance (in feet) of maximum migration, or distance to affected structure.

** Personal injuries sustained and/or death occured.

\+ Landfills are municipal solid waste landfills (publicly or privately owned/operated) unless otherwise noted.

Sources

1. UPI or other news sources
2. SCS Engineers
3. Contact with local officials
4. Princeton's Risk Assessment of the Monument Street Landfill
5. "Gas Control in Landfills: A Case Study" paper presented by Donald L. Feuerstein at the Fifth National Congress On Waste Management Technology and Resouce and Energy Recovery, Dallas, TX, December 7-9, 1976.

EXHIBIT 8-4 (con't)

LANDFILL GAS MIGRATION DAMAGE CASES

Landfill Name, Location, and Date	Methane Detected Off-Site Above LEL?/ Distance*	Explositon/ Fire?**	Landfill Characteristics and Corrective Action	Damages and Other Comments	Data Sources
Anderson Township Landfill Cincinnati, OH 1983	Yes/300	Yes** Off-Site	No liner present. Control system installed after the incident.	Explosion destroyed residence across the street from the landfill. Minor injuries reported.	2
Warner Hill Landfill Cleveland, OH 1980	Yes/100	Yes** Off-Site	No liner present. Soils consist of silt and clay. Control system installed after the incident.	Explosion killed foundry worker on site adjacent to landfill.	2, 3
Fells Street Landfill Richmond, VA 1975	Yes/20	Yes Off-Site	No liner present.	In 1975, explosion occurred in nearby apartment building. The City decided to buy and demolish it. Two schools sited on the landfill were closed until a control system was installed.	2, 3
Fells Street Landfill Richmond, VA 1982	No/N/A	Yes** On-Site	No information available.	The 1982 incident occurred when children trespassed onto the landfill site, entered a control system manhold, and lit a match, resulting in an explosion. The nature of the associated injuries has not been disclosed. The case is in litigation.	2, 3
Ocean County Landfill Manchester, NJ December 1983	No/N/A	Yes On-Site	Ventilation and alarm systems to be installed in the remaining maintenance garage.	Spark from landfill pump probably ignited methane gas, causing explosion and fire. One person sustained first and second degree, and flash burns. Office building destroyed.	1
Wanaque, NJ March, 1984	No information available	Yes	Control system proposed for school located on a closed landfill.	No information available.	1
Babylon Landfill Comack, NJ May 1984	Yes/50	Yes** On-Site	No liner present. Sandy soils. Control system installed after incident.	Methane migrated to the scalehouse on-site. Explosion killed one person and injured another.	1, 2

<u>Symbols and Sources</u> (Refer to first page)

EXHIBIT 8-4 (con't)

LANDFILL GAS MIGRATION DAMAGE CASES

Landfill Name Location, and Date	Methane Detected Off-Site Above LEL?/ Distance*	Explosion/ Fire?**	Landfill Characteristics and Corrective Action+	Damages and Other Comments	Data Sources
Monument Street Landfill Baltimore, MA. April 1983	Yes/No information available.	No	Solid waste with illegally-dumped hazardous waste. Soil type is clay with sand lenses. Native clay serves as a liner.	Vent pipes were not maintained causing vents to become non-functional. Street light fire was believed related to methane migration. Ongoing lawsuit concerns presence of priority pollutants.	1, 3, 4
PJP Landfill Jersey City, NJ 1984	No/N/A	Yes On-Site	Solid waste with illegally-dumped hazardous waste. An NPL site.	Landfill fires causing air pollution have been a problem for years.	2
Mission Avenue Oceanside, CA 1981	Yes	No	No liner present Control system installed after the incident.	Schools surrounding the landfill were evacuated and classes were suspended for 4-5 months.	2
Unnamed Landfill Adams County, CO 1977	Yes	Yes** Off-Site	No information available.	Explosion caused two fatalities and injured seven others at a pipeline construction project adjacent to the landfill.	2
Reilly Construction Company Springfield, IL 1979	Yes/200	Yes** Off-Site	No liner present. Control system installed after the incident.	Methane migrated into construction company offices adjacent to the landfill. Limited fires occured. No explosion. Building evacuated and use restricted for four weeks.	2
Campground Landfill Louisville, KY 1978	Yes/200	No	No liner present. Soils are sandy with clay and silt layers interspersed. Control system installed after the incident.	No physical damages occured. Buildings evacuated for short period of time.	2

Symbols and Sources (Refer to first page)

EXHIBIT 8-4 (con't)

LANDFILL GAS MIGRATION DAMAGE CASES

Landfill Name, Location, and Date	Methane Detected Off-Site Above LEL?/ Distance*	Explosion/ Fire?**	Landfill Characteristics and Corrective Action+	Damages and Other Comments	Data Sources
Lees Lane Landfill Louisville, KY 1978	Yes/1,000	Yes** Off-Site	No liner present. Soils are clayey silt to gravelly sand. Control system installed after the incident.	Small fires and explosions. Several houses evacuated and condemned. Benzene (29.5 ppm) and Vinyl chloride (17.9-122.6 ppm) detected off-site.	2
Allegheny County Landfill Frostburg, MD 1978	Yes/200	Yes** Off-Site	No liner present. Soils are silt and clay. Control system installed after the incident.	Limited fire in off-site equipment maintenance building. No explosion. Building use restricted for two months. Building was highly ventilated until gas control system installation.	2
Beantown Dump Rockville, MD 1980	NO/N/A	Yes** Off-Site	Old, inactive dump site. Building constructed on inactive disposal site. Control system installed after the incident.	Small explosion occurred in enclosed back room of auto body shop. A janitor was injured. Shop closed for one month until control system was installed.	2
Winston Salem, NC 1969	Yes/100	Yes** Off-Site	Codisposal No liner present. Control system installed after the incident.	Methane migrated into National Guard Armory. Explosion killed three guardsmen, seriously injured twelve, and twenty-five other guardsmen experienced less serious injuries. Seven of the injured have become partially or completely disabled.	
Port Washington Landfill North Hempstead, NY 1981	Yes/200	Yes** Off-Site	Liner present Soils sandy with some clay and silt layers.	Small explosions in furnace rooms of several homes. Minor damage occurred. Furnaces were replaced.	2
Smithtown Landfill Smithtown, NY 1984	Yes/200	Yes** Off-Site	Liner is present. Soils are sandy	Explosion damaged room in transfer station.	2

Symbols and Sources (Refer to first page)

EXHIBIT 8-4 (con't)

LANDFILL GAS MIGRATION DAMAGE CASES

Landfill Name, Location, and Date	Methane Detected Off-Site Above LEL?/ Distance*	Explosion/ Fire?**	Landfill Characteristics and Corrective Action+	Damages and Other Comments	Data Sources
Hardy Road Landfill Akron, OH 1984	Yes 500-1,000	Yes** On-Site	No liner present. Control system installed after incident.	One house destroyed. Ten houses evacuated temporarily. Several minor injuries.	1, 2
Landfill near Lake Township Canton, OH 1984	Yes/No information available	No	No information available.	Two homes and a day care center temporarily evacuated.	1, 2
Tyler, TX May 1982	No/N/A	No	Control system existed prior to incident.	TDPS office building sited on closed landfill. Methane has caused problems since early 1970's. Failure of ventilation exhaust fan resulted in "significantly high" levels of methane in the building.	1
I-95 Landfill Lorton, VA 1984	Yes 300-1,000	Yes++ Off-Site	No liner present. Soils range from clay to sandy clay to sand. Control system installed after the incident.	One man was fatally injured and another burned over 50% of his body during explosion and limited fire.	1
Greentree Hills Landfill Madison, WI	Yes 100-150	Yes** Off-Site	Soils are composed of clay, glacial fill, sand, weathered and fractured bedrock.	Explosion blew out one sidewall of a townhouse. Three adjacent apartment buildings and several homes evacuated for 20-30 days. Two people seriously injured. Claims filed against the City total $5.2 million dollars.	1, 3

Symbols and Sources (Refer to first page)

Gas control systems are required at sites where methane concentrations exceed the LEL in soils at the property boundary or 25 percent of the LEL within structures on the property. In addition, Florida's sanitary landfill criteria require that, "All sanitary landfills where gas generated by decomposition of wastes is not readily dispersed into the atmosphere shall be provided with a gas control system."(3) The criteria further requires that emissions from a gas control system not violate state air quality standards. Gas control systems have also been installed to reduce odors.

Most States have adopted EPA's criteria for methane concentrations in on-site structures and in the soil at property boundaries, or have more stringent criteria. For example, the State of Washington requires that methane must not be present in off-site structures above 100 parts per million by volume of hydrocarbons. Their criteria apply to both operating landfills and those closed after the effective date of the legislation, November 27, 1985.(4) Landfill operators in Washington State may be required to monitor for LFG at the property boundary and in on-site structures and to report the results to county health departments on a quarterly basis. A State-approved LFG monitoring plan may be required. Operators of large landfills in Washington (greater than 10,000 cu. yd. per year) must continuously collect methane either for sale, for flaring, or for utilization as energy. However, operators of smaller landfills are not subject to this requirement, and may vent LFG in lieu of the above.(4)

OTHER ENVIRONMENTAL CONSIDERATIONS

Aside from safety aspects of explosion and fire, there are other environmental concerns associated with landfill gas and collection systems. First is the subject of condensate. When landfill gas is first removed from extraction wells, it is usually quite warm and high in entrained moisture which will drop out as liquid (or "condensate").

In general terms, there are two types of condensate associated with collection systems. The first type drops out in collection pipelines. Unless handled properly, these liquids can accumulate at low points and eventually block gas flow. To prevent this, collection piping is sloped to pre-defined low points. Dedicated "moisture traps" collect condensate for control.

The second type of condensate is that which drops out at the gas processing facility, usually the result of active LFG dehydration. Most States will not allow disposal of these liquids back to the landfill. States typically require that these liquids be treated and/or hauled off-site. Depending on composition, condensate may be a hazardous waste, increasing further the cost for condensate handling.

Trace constituents are a second environmental concern associated with gas control and recovery systems. Trace constituents comprise less than one percent of LFG, and may include volatile organic compounds (VOCs). Vinyl chloride, benzene, toluene, and xylene are examples of VOCs. Many of those compounds are toxic at certain concentrations. Though the concentrations of those compounds do not usually exceed applicable health standards, they may exceed some State ambient air guidelines/ standards in some instances, and have garnered attention from State and local regulatory authorities. Proper LFG control and combustion should reduce VOC concentrations to below acceptable levels.

A third environmental concern is flaring of LFG. Disposal of collected LFG can be a problem at gas control sites, or even recovery sites where more gas is withdrawn than can be used. If freely vented, LFG can cause odor problems and/or other concerns (see above). The usual approach is to combust the gas on-site. Simple combustion uses the methane content of the LFG itself, and auxiliary fuel is not usually required. Burning the LFG is mostly successful in abating any odor problems (malodorous compounds are destroyed), and in reducing VOCs to safe levels. LFG combustion can be performed with simple candle flares, or with more sophisticated combustion units (e.g., ground flares and even incinerators) which enclose the combustion process, may require auxiliary fuel, and generally achieve greater gas destruction.

REFERENCES

1. Personal Communication, Lewis Audette, President, New England Alternate Fuels, June 2, 1986.

2. National Fire Protection Association, Fire Protection Guide on Hazardous Materials, 7th Edition. Section 325 M. 1978.

3. Florida Administrative Rules 17-7.073, Sanitary Landfill Closure Plan Requirements.

4. Washington Administrative Code 173-304, Minimum Functional Standards for Solid Waste Handling.

SECTION 9

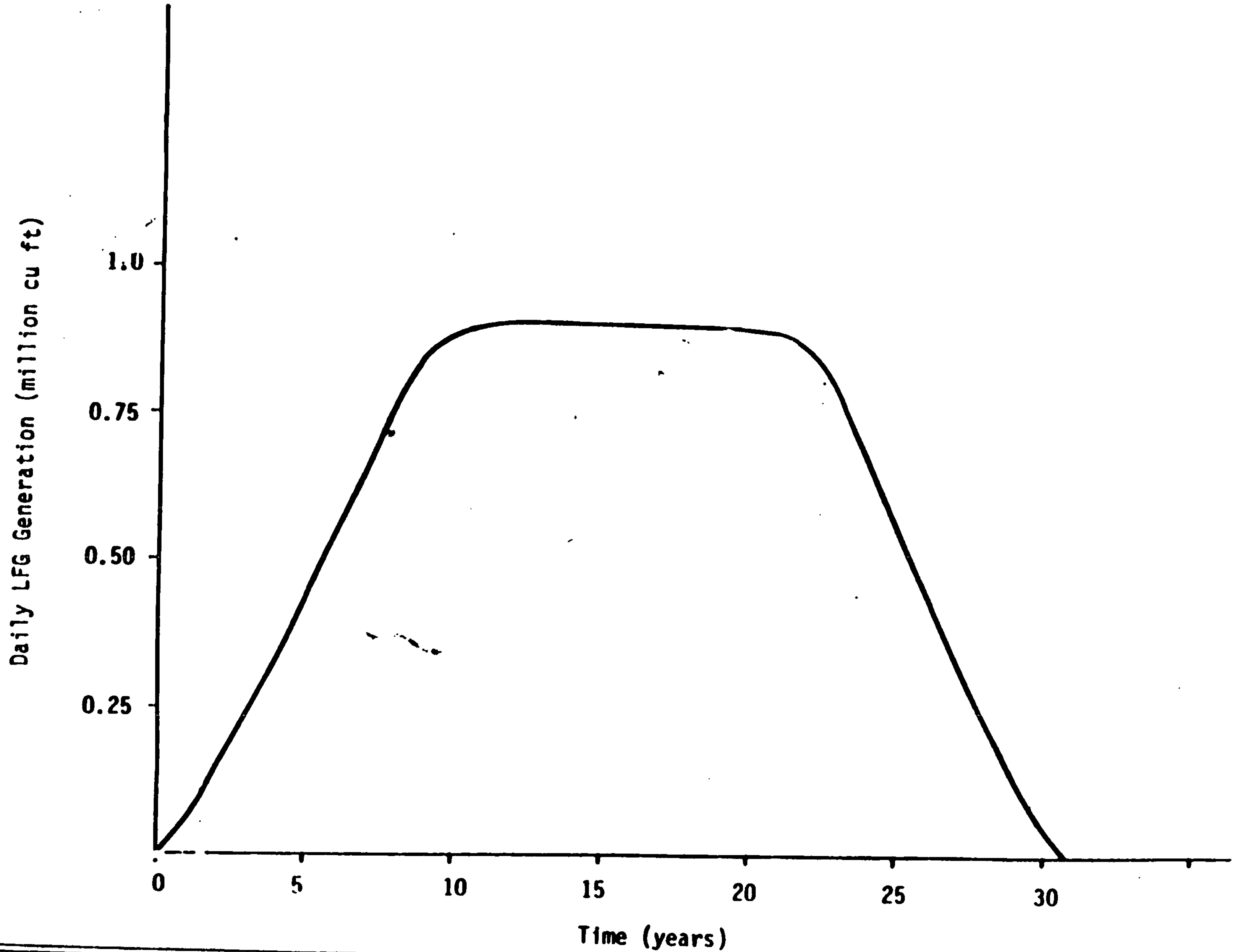
LANDFILL GAS GENERATION

When organic matter decomposes, it is transformed into a variety of simpler organic materials by the action of micro-organisms abundant in solid waste. Some of the components in the solid waste have already begun to decompose before being disposed in a landfill. Typically, early decomposition of such components is caused by aerobic bacteria utilizing readily available oxygen. The oxygen is readily depleted and anaerobic processes then begin decomposing the organic constituents.

These processes, both aerobic and anaerobic, produce principally methane and carbon dioxide. The rate of the LFG production is dependent on a number of site-specific factors, including the age of the landfill, moisture content and solid waste composition and quantity. Other factors that affect LFG generation are temperature conditions in the landfill, nutrients, infiltration of oxygen, and the in-place density of the refuse.

LFG generation begins almost immediately upon burial and increases rapidly with steady generation beginning within several months to a year. Relatively steady generation may continue for ten years or longer.(1) Thereafter, the generation rate decreases, but gas generation continues for many years. These changes in generation rates are illustrated in Exhibit 9-1 and are based on the assumption that LFG generation is based on so-called "zero order reaction rates". Not all authorities agree with this assumption and since LFG research has only been

EXHIBIT 9-1 EXAMPLE OF LFG GENERATION VS TIME



conducted for the past 10 to 15 years, little data are available to support one hypothesis over another.

There is current research relating to enhancing methane production through utilization of sewage sludge. Preliminary results show that with the addition of sludge cake to municipal refuse, the production of LFG is hastened. Total gas production from test cells vs. control cells (those without sludge added) is about the same.

REFERENCES

1. Lockman and Associates, Inc. Recovery, Processing, and Utilization of Gas from Sanitary Landfills. U.S. Environmental Protection Agency. Report No. EPA-600/2-79-001. February 1979.

SECTION 10

LANDFILL GAS RECOVERY

Recovery of LFG for beneficial use is currently practiced at more than 50 locations nationwide with more than 40 other systems in the planning stages, as shown in Exhibits 8-1 and 8-2 respectively. This section addresses four topics related to LFG recovery: uses of recovered gas, criteria for the selection of sites suitable for gas recovery, technical factors related to LFG recovery, and LFG processing techniques.

USES OF RECOVERED GAS

LFG can be used directly as a medium-Btu fuel or upgraded through processing to a higher heating value. LFG recovery projects to date have concentrated on three general uses:

- Direct use of medium-Btu gas by industrial customers after minimal processing for water removal.
- Combustion of medium-Btu gas to generate electricity for sale to the local utility.
- Upgrading of LFG to pipeline standards (high-Btu) for injection into utility (natural gas) pipelines.

The production of medium-Btu gas for direct use in boilers or similar applications is the simplest process. In this case, LFG is typically processed to remove entrained moisture and particulates. The product gas has an energy value ranging from 400 to 600 Btu per cu. ft.(1), making it suitable as a boiler fuel, and can be sold for this purpose to industries nearby. Industries currently utilizing LFG include refineries, chemical plants, and power plants.

Medium-Btu LFG can also fuel internal combustion engines or gas turbines to generate electrical power after moisture, particulates, and corrosive materials have been removed from the gas. Although steam boilers could provide higher efficiencies than internal combustion engines, the capital and operational costs of a steam plant require a large-scale operation (greater than 20 megawatts) to be economically viable.(2) At present, no LFG recovery projects employ a steam boiler for on-site power production; only some of the nation's largest landfills, such as the Fresh Kills Landfill on Staten Island, produce enough LFG necessary to run a 20 mW (megawatt) plant. Generation of electricity may be enhanced with passage of legislation requiring public utilities to purchase electricity from qualifying facilities at the utility company's avoided cost. The avoided cost represents the cost to the electric utility of generating the next increment of electricity. However, these prices are sensitive to costs for fossil fuels used to generate electricity.

The third category of LFG use is upgrading to pipeline quality standards. The production of pipeline quality gas (950 to 1,000 Btu per cu. ft.) requires removal of carbon dioxide, moisture, and particulates, and possibly other trace gases. Carbon dioxide can be removed via several treatment processes including physical absorption, chemical absorption, and membrane separation. If nitrogen is present, it can be removed by fractional liquifacation. The cost is usually so great, however, that this option is precluded when significant air (nitrogen) intrusion is present. Because of this, high-Btu gas production systems typically withdraw less of the available LFG than other systems in order to prevent the air intrusion caused by high pumping rates.

CRITERIA FOR SITE SELECTION

The quantity, quality, and ability to collect LFG, and the availability of markets are factors critical to the success of a LFG recovery project. Until LFG is collected and sold, it is merely a waste product representing a potential odor or migration liability.

Assuming that LFG markets are present, potential recovery sites are generally evaluated based on the following five criteria:

1. Amount of refuse -- The quantity of LFG produced depends first on the amount of refuse available for decomposition. For commercial applications, an LFG recovery site should have a minimum of roughly one million tons of refuse in place, an average depth of 40 feet, and a fill area of 40 acres.(1) These figures are general guidelines based on engineering experience. Generally, sites which fall below these limits are too small (thus producing too little gas to be economically recovered and used), or too shallow (thus making it difficult and/or expensive to recover). An engineering evaluation and projection of LFG use for each site should be conducted.
2. Refuse composition and moisture content -- Waste composition can limit both the total yield and rate of LFG

production. In general, LFG production is stimulated by a waste having a high percentage of readily decomposable organic materials (e.g., food and garden wastes). The recoverable landfill gas is derived from biodegradation of these and other organic constitutents. Sufficient moisture must be present to support the biological activity and nutrient transport necessary for LFG production. Moisture content and movement are generally the limiting factors in LFG production, with disposal sites in arid locations generating LFG at a slower rate for a longer duration. Too much moisture can inhibit LFG migration to the collection system, plug collection wells, and promote the generation of leachate. In addition, toxic industrial wastes or other inhibitory materials present can upset the activity of methane-forming bacteria and reduce LFG generation rates.

3. Age of the landfill -- As biodegradation of organic materials is completed, LFG production is reduced to a minimal level. Therefore, older disposal sites will produce less LFG because the decomposition rate has decreased. The rate of LFG generation through decomposition of buried wastes determines the useful life of a landfill for gas recovery. This generation rate varies significantly among landfills, but the total volume of LFG generated is thought to be fairly constant.

The area under the curve illustrated in Exhibit 9-1 is the total volume of LFG generated. Basically, the LFG generation rate increases with time during active filling. Shortly after filling is complete, the rate levels off and remains relatively constant. This steady-state condition may endure 10 or more years, depending on the actual conditions which exist in the landfill. For example, a moist landfill with a high generation rate per unit mass will have a shorter life than a dry landfill with a lower generation rate.(3) In either case, a point is reached where the generation rate begins to decline as the quantity of decomposable matter decreases. At some stage, the rate of LFG production is reduced to an amount below that necessary for viable recovery.

4. Receipt rate -- The average age of the refuse in a landfill is directly related to the rate at which refuse was received during the site's operational life. The lower the receipt rate, the greater the decomposition at the time of closure. To assure an adequate quantity of LFG production, a potential recovery site should have a receipt rate of at least 400 tons per day or more.(4) However, much smaller sites are recovering LFG, including the landfill at Brattleboro, VT, where waste receipts average less than 40 tons per day.(5)

5. Permeability of cover and surrounding soils -- Landfill sites constructed in or with impermeable soils or materials are favorable for LFG recovery. Because LFG tends to travel the path of least resistance, its tendency to migrate increases with the permeability of surrounding soils. High permeability soils, i.e., sand and gravel, allow LFG to escape from the landfill, thereby inhibiting recovery. Landfills constructed with impermeable materials, such as clay soils and synthetic caps, prevent the escape of LFG and inhibit the entry of air into the landfill during LFG recovery. This containment is important because air decreases LFG quality and also inhibits methane production by anaerobic bacteria.

At closure a sanitary landfill is to be provided with a cap of compacted soil. Such caps decrease LFG escape through the surface. Post-closure construction activities such as paving or compacting the landfill surface also aid in preventing LFG escape. However, one drawback of making the landfill surface less permeable is that it promotes lateral migration if the surrounding subsurface soils are more permeable than the cap. Thus, if LFG is not being extracted from a capped landfill, the landfill perimeter should be monitored to detect any migration and identify the possible need for LFG control.

TECHNICAL FACTORS RELATED TO LFG RECOVERY

The first component in LFG recovery is the collection system. The design of the collection system depends primarily on landfill conditions. LFG collection typically involves an induced exhaust well system, which extracts LFG through a network of wells joined by a header pipe to a blower. Exhibit 10-1 depicts a typical layout of an extraction system. Wells are drilled in the refuse with perforated pipe placed into a gravel-packed section of each boring. This perforated zone is typically designed to be about half the depth of the well and is located in the lower portion to minimize air intrusion. Exhibit 10-2 shows a detail of a typical LFG extraction well. Other design elements include the well depth, spacing, and setback distance from the landfill perimeter.

The design of the collection system does not depend on the intended end use for the LFG, but rather on landfill conditions. For example, recovery well depths are typically designed to be 50 to 90 percent of the landfill depth.(6) Similarly, the setback distance from the landfill perimeter will depend on the cover material. Since the permeability of the cover material determines the likelihood of air intrusion through the side slopes, the setback distance will vary accordingly to minimize intrusion. The steepness of the sideslopes must also be considered since flatter slopes decrease the possibility for such intrusion.

Well spacing depends on the planned flow rate, and is

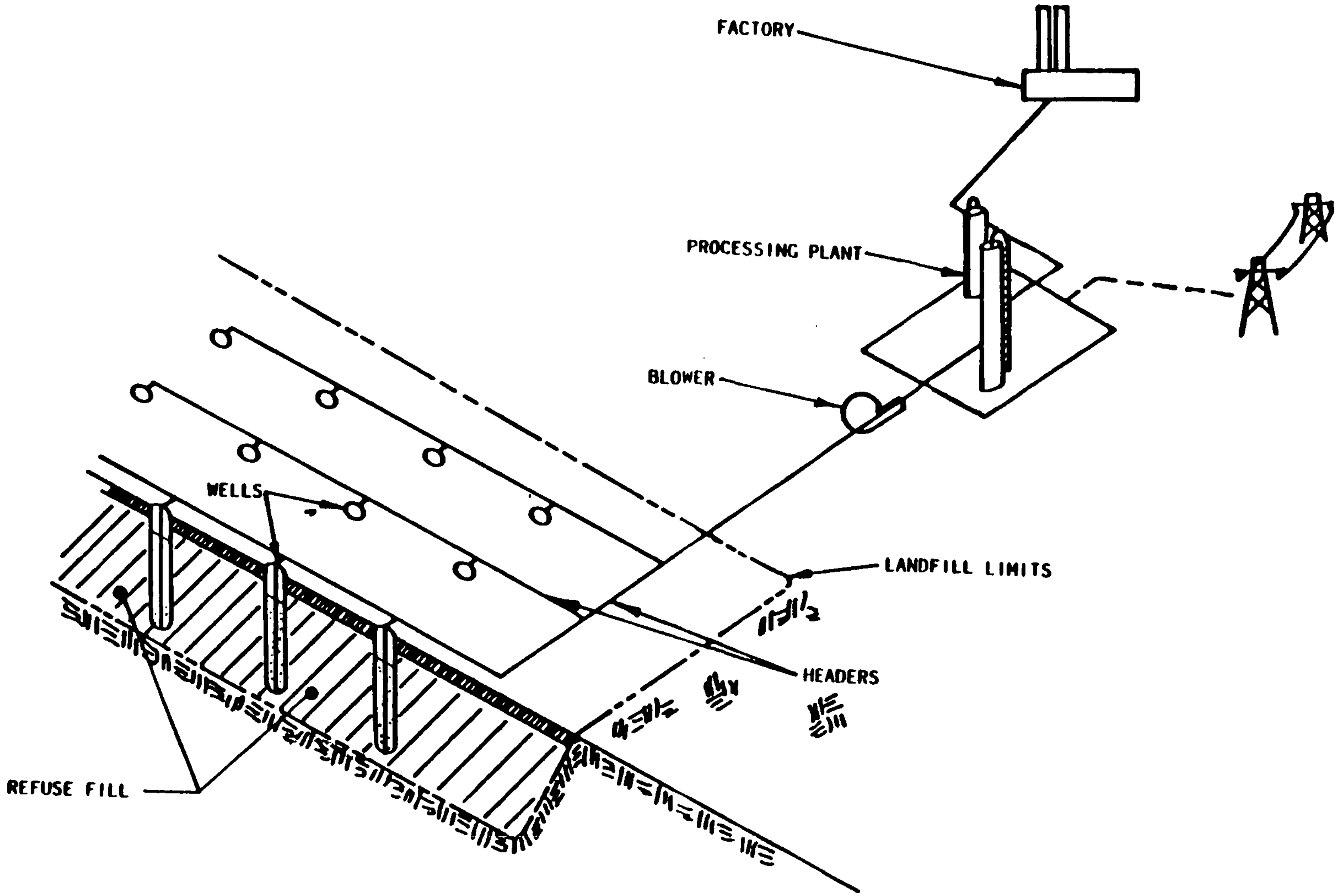


EXHIBIT 10-1 LANDFILL GAS RECOVERY SYSTEM

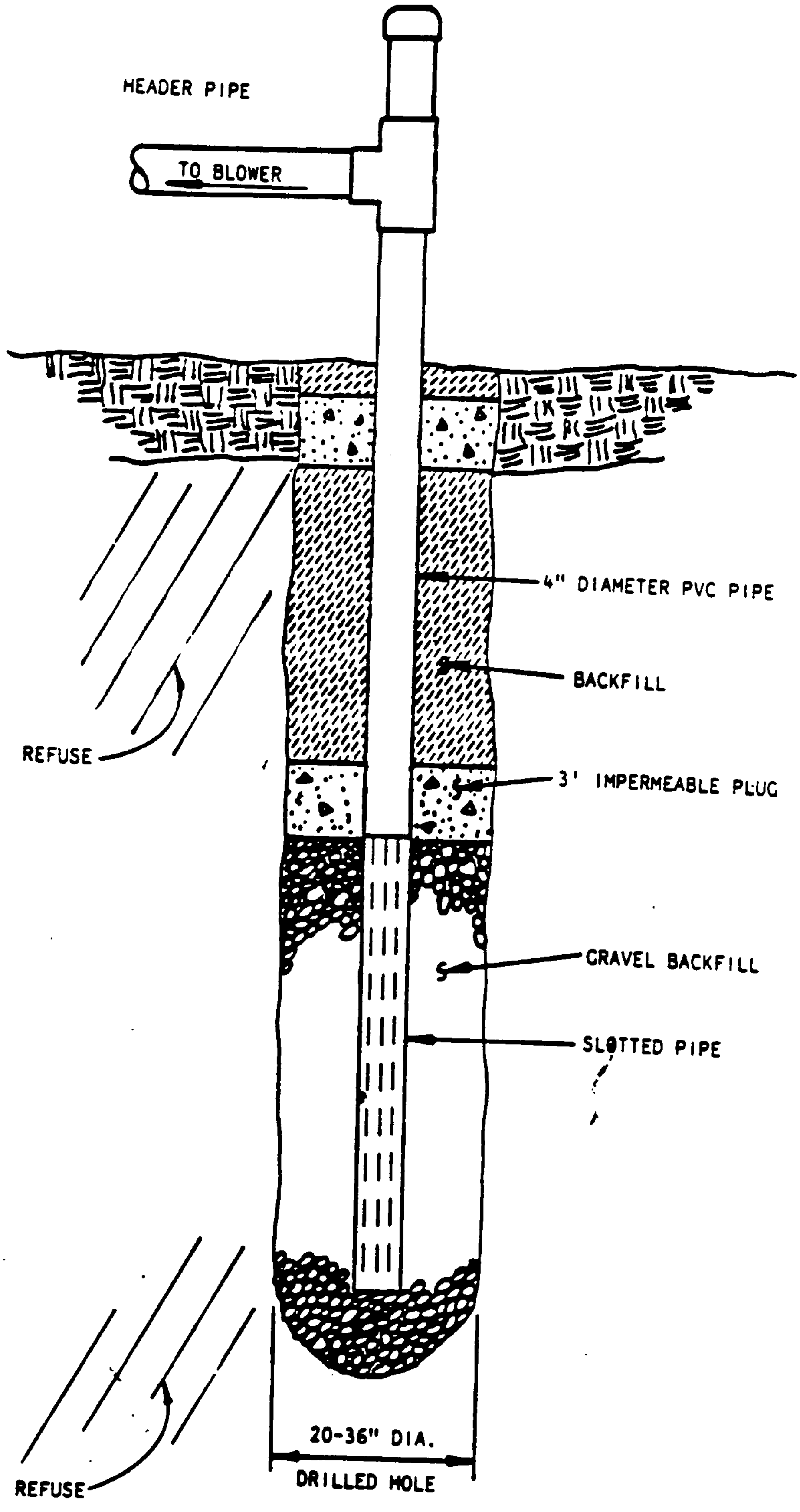


EXHIBIT 10-2 TYPICAL EXTRACTION WELL INSTALLATION

usually based on a concept called the "radius of influence." The radius of influence describes that landfill area within which the extraction well causes a change in pressure. The size of the radius depends on such parameters as refuse density, LFG production rate, and landfill depth, and is often determined empirically, using data from a pump test program. A typical test program will apply varying pumped withdrawal rates to an extraction well, and measure the corresponding pressure changes in surrounding monitoring wells. After the radius of influence is estimated, the well-spacing for the full-scale design can be determined.

In addition to the vertical well systems described above, LFG can also be extracted by means of a trench collection system, also called a horizontal well system. This type of system requires installation of trenches as the landfill progresses. The trenches consist of rows of crushed stone running the length of the landfill and located at various levels as the landfill expands vertically. The stone surrounds a perforated pipe connected to a header pipe at one end, and as with a vertical well system, LFG is extracted by a blower connected to the header pipe.

Regardless of the type of collection system, vertical or horizontal wells, the rate of LFG production at the specific site determines the upper boundary of recovery rates. Ideally, the recovery system should collect LFG at the same rate it is being produced within the landfill. Under such ideal conditions, no LFG would be available for migration, and no air would be drawn into the landfill.

A well-designed and constructed recovery or control system need not have negative impacts on the end use of the site. Both horizontal and vertical well systems can be built with virtually all collection pipes and equipment below the surface. Only blowers, gas processing equipment, controls, and flares are above the surface, where they can be centrally located and designed for minimum visual and operational impact. An excellent example of a methane recovery system designed to complement landfill end use is the Industry Hills Civic-Recreational-Conservation Area located in the City of Industry, California. There, a vertical well system recovers methane from a closed municipal landfill. The surface of the site is used as a golf course with the gas used for space and water heating at a convention complex next to the golf course. This project was selected as the Outstanding Civil Engineering Achievement of 1981 by the American Society of Civil Engineers.(7)

LANDFILL GAS PROCESSING

Landfill gas is seldom used directly upon withdrawal from a site. The type and degree of processing depends on the characteristics of the gas and the end use. Exhibit 10-3 illustrates typical processing steps. Each step is briefly described below followed by a methanol process that combines three operations.

Particulate Removal

Particulates are sometimes entrained in the LFG stream as the gas is drawn from the landfill. The simplest removal technique is reduction of gas velocity, whereby LFG passes through a tank-like vessel where its velocity decreases and particulates drop out via gravity. Another method is the use of a venturi scrubber.

Trace Constitutent Removal

Trace constituent removal can be accomplished using any of a number of solvent, membrane, and carbon treatment systems. For example, the solvent process involves absorption of these constituents in a relatively small amount of the solvent, which is regenerated by application of heat sometimes aided by the addition of air. The membrane technology process, also called physical membrane separation, is a proven technique for removing trace constituents (gases) using mechanical separation.

Carbon Dioxide Removal

Carbon dioxide is removed for high-Btu applications. Its removal results in the production of pipeline quality methane. The most practiced methods by which carbon dioxide is removed from LFG are adsorption. Carbon dioxide removal can also be accomplished using membrane technology.

Dehydration

Landfill gas usually has a high moisture content as it first comes from a well collection field. This moisture is highly corrosive, and can cause problems with recovery, processing, transmission and user equipment. Depending on the initial moisture content and the end-use requirements, various methods can be applied to remove this water. Once removed,

EXHIBIT 10-3

GENERALIZED SCHEMATIC OF LFG PROCESSING

Raw LFG

↓

Particulate Removal

↓

Compression/Dehydration

↓

Trace Constituent Removal

↓

Carbon Dioxide Removal*

↓

End Use

NOTE:

Any combination of unit processes may be used depending on gas characteristics and end use.

* Only for high-Btu applications

the liquid is known as condensate.

One way in which water is removed from the gas stream is cooling of the gas. A certain amount of cooling is inevitable in any collection system, as hot gas is removed by wells deep in the landfill and brought into contact with cool ambient air in collection pipes on or near the surface. This liquid is collected and controlled via "moisture traps" (see page 8-15).

Additional processes can further reduce the remaining moisture content of LFG. One of the most effective approaches for a landfill gas application is cooling of the gas using mechanical refrigeration. The refrigeration cools the gas to a temperature usually above 32° F and condenses the majority of the water vapor. The water vapor is then separated as a condensate and the partially dehydrated gas is then available for use. Additional dehydration can be achieved by reducing the temperature to below 32° F. However, in order to avoid freezing, a substance such as methanol must be injected so that the condensate can be removed as a liquid.

Other methods of dehydration have been attempted with LFG but have not been completely successful. These methods include the use of triethylene glycol which is used in the natural gas industry for dehydration. This method is sensitive to chlorides and oxygen that may be present in LFG and will deteriorate the glycol solution, creating a corrosive product.

Methanol Wash

Methanol wash is a non-proprietary process that removes chlorinated trace constituents, carbon dioxide, and moisture in a single process. It is based on the process of using methanol for removal of trace constituents and carbon dioxide from coal gas and natural gas. Several variations on the methanol wash process have been demonstrated at the pilot scale. This process offers the promise of being an economical way to remove trace constituents, carbon dioxide, and moisture.

REFERENCES

1. Johns Hopkins University Applied Physics Laboratory. Landfill Methane Utilization Technology Workbook. Prepared for U.S. Department of Energy, Division of Building and Community Systems.

2. Gas Recovery Systems. The Economics of Landfill Gas Projects. GRCDA 9th International Landfill Gas Symposium, May 1986.

3. SCS Engineers. Toyon Canyon Landfill Gas Utilization Study. Prepared for Bureau of Sanitation, Department of Public Works, City of Los Angeles, California. December 1982.

4. Bogardus, Ellen R. Landfill Gas Recovery Comes of Age. 14th Composting and Waste Recycling Conference, Washington, D.C. May 8, 1984.

5. Personal Communication with Lewis Audette, President, New England Alternate Fuels, June 2, 1986.

6. EMCON Associates. Methane Generation and Recovery From Landfills. Ann Arbor Science. Ann Arbor, Michigan. 1982.

7. Ugly Dump Site Transformed Into Recreation Mega-Facility. Civil Engineering, American Society of Civil Engineers. Vol. 51, No. 6. June 1981.

SECTION 11

SAFETY CONSIDERATIONS AND POTENTIAL CONSEQUENCES OF NOT RECOVERING OR CONTROLLING LANDFILL GAS

SAFETY

Safety is a primary concern in dealing with any combustible gas. Landfill gas is combustible and can cause explosions and fires if allowed to accumulate in confined areas. Subsurface features such as underground trenches, vaults, utility conduits, and other structures may allow gas to accumulate. LFG can also be an asphyxiant displacing oxygen in enclosed areas.

Structures on closed landfills should be monitored and protected from LFG. Closed landfills operated as recreation areas or other public uses should include LFG protection for restrooms, pavilions, equipment and administrative buildings, and other enclosed structures. The dangers of LFG may mandate strict safety precautions at closed landfills, particularly during construction. Testing of the subsurface and the near-surface atmosphere at construction sites may dictate appropriate safety measures, including forced ventilation, specialized breathing apparatus, or non-sparking tools and equipment.

Closed landfills present potential LFG problems for buildings both on and near the site. Closure of landfills includes installation of an impermeable cap to prevent moisture movement through the solid waste and subsequent production of leachate. The cap also retards emission of gas through the landfill surface. The subsequent LFG production creates pressure in the landfill, forcing the gas to migrate laterally through the most permeable soil lenses. Gas has been documented to travel up to several thousand feet laterally from a site (see Exhibit 8-4). Whenever structures are located near landfill areas, monitoring should be performed to determine if gas is migrating toward the structure. Site conditions may preclude migration; however, landfills can be expected to generate LFG, and should be assessed by specialists familiar with gas migration and control. In questionable situations, subsurface gas monitoring may be appropriate. If gas is found in the soil at the property boundary at or above the LEL, an engineered control system is needed.

POTENTIAL CONSEQUENCES OF NOT RECOVERING OR CONTROLLING LFG

The consequences of not recovering or controlling LFG from a landfill will vary according to the site conditions and the quantity of gas generated. The potential consequences, both environmental and economic, however, can be quite significant. Foremost, is the danger of LFG migration that is likely to occur without recovery or migration controls. LFG migration presents serious risks, including fire, explosion, and asphyxiation, to residents and workers on and near a landfill. LFG can also be harmful to vegetation. It is an asphyxiant to many plants, trees, and shrubs, causing vegetative kills by precluding the presence of air at normal levels.

Without recovery or migration control, the primary mechanism preventing migration is the natural venting of LFG into the atmosphere. However, this may cause environmental problems in the form of odors. Although methane is odorless, other constituents of LFG, such as hydrogen sulfide, are odorous even in trace quantities. Some LFG control systems incinerate the gas to control odors; others merely vent to the atmosphere with no odor treatment.

Although they are effective in controlling LFG hazards, control systems without recovery do not take advantage of the potential economic benefits. LFG recovery systems can provide revenue through the sale of generated electricity or gas. In addition, the use of LFG reduces the overall consumption of non-renewable fuels. Therefore, LFG recovery systems should be considered over control-only systems at landfill sites where recovery is economically feasible. At sites where recovery is unwarranted, LFG control measures may still be necessary to protect the surrounding area and allow future use of the closed landfill. Where recovery is warranted, separate control features may be required beyond that included in a recovery system to ensure that complete control coverage is provided.

SECTION 12

FACTORS AFFECTING ECONOMICS OF GAS RECOVERY

LANDFILL CONSIDERATIONS

In assessing the economic viability of landfill gas recovery, the landfill characteristics are the first set of conditions to be investigated. These characteristics impact the quantity of gas generated, the percentage that can be collected, the quality of the gas, and the gas generating lifetime. Generally, three factors influence total gas generation: (1)

1. Waste Quantity. All things being equal, landfills with more waste will generate more gas than smaller sites. Thus, gas recovery and utilization is generally more profitable at sites with large quantities of refuse. One million tons of refuse in place is a commonly-used minimum figure. However, smaller sites may be economically viable.

2. Age of the Waste. If the refuse was recently deposited, it is likely to be at its peak generation rate. Refuse in-place for 10 to 20 years may have passed this peak, and recoverable quantities of gas will be less than at younger sites.

3. Other Considerations. Factors relating to the type of waste and its current condition include moisture content, pH, organic content, etc.

The second set of considerations relating to landfill gas recovery deals with collection capability. The following factors affect collection capability: (1)

1. Depth vs. Area. Deep landfills are preferable to those spread out over large areas and shallow depths. Generally, landfills more than 40 feet deep allow collection of a high percentage of the gas generated. In addition, collection systems are less expensive when one deep well can collect gas from the same waste volume as multiple shallow wells.

2. Mounded vs. Subsurface Configuration. The less surface area exposed to atmosphere, the less gas will dissipate into the air and escape the collection system. When landfills are constructed below grade, a larger portion of gas generated can be recovered than from mounded fills.

3. Cover Soil Permeability. Generally, the tighter the cover soils, the greater the gas retention and the greater volume of gas collected. Permeable cover soils allow gas to dissipate to the atmosphere and escape the collection system.

4. Water Content. High moisture content at the site generally increases the rate of waste decomposition and gas generation compared to dry sites. Higher gas generation rates normally improve the viability of a gas recovery project. Excessive moisture in

the fill, however, can be a problem because if wells flood with water, the ability to collect the gas is reduced.

MARKET CONSIDERATIONS

All existing landfill gas recovery and utilization projects can be classified into three general types: (1) medium-Btu applications, (2) electric generating applications, and (3) high-Btu applications. Market considerations that impact gas recovery viability differ according to those types of end uses.

Medium-Btu Uses

Typical medium-Btu gas uses include boiler fuel, space heating, water heating, steam generation, or industry-specific process applications. In these cases, only nominal removal of particulates and moisture is performed before the gas is used. Typically, medium-Btu gas applications entail transmission of the gas to users near the landfill site. Factors impacting the viability of medium-Btu applications include:

1. Proximity of User. This is a critical consideration in the viability of a medium-Btu project. A market should exist near the landfill gas site (e.g., within 5 miles) in order for the gas to be transmitted at reasonable cost.
2. Transmission Distance and Access. As the transmission distance increases, the cost of installing and maintaining transmission lines increases proportionately. Consideration must be given to the distance, securing

right-of-way, terrain, obstacles such as rivers, and transmission line maintenance over such distances.

3. Quantity of Gas Used. Ideally, most or all of the landfill gas that can be collected should be used.

4. Variability of Gas Use. Natural gas use (and potential landfill gas use) for space and water heating, may be highly seasonal. Under these circumstances, gas demands may be quite high during the winter months, but demand could be low or non-existent during warm summer months. During these times, the landfill gas cannot be stored, but rather is vented to the atmosphere or flared without economic return. Intermittent operations are also undesirable. The ideal medium-Btu user is one that consumes the landfill gas for process uses at uniform rates throughout the year with operations 24 hours per day, 7 days per week, and 52 weeks per year.

5. Quality Requirements. The quality needs of the medium-Btu user are highly variable. The first quality requirement relates to moisture content. Landfill gas is wet compared to natural gas, and some users may be able to tolerate a relatively wet gas, but others may not. If the gas must be as dry as natural gas, considerable capital expense may be required to remove the moisture.

6. Trace Constituents. Aside from removing moisture from the gas stream, other trace constituents are present that may have a deleterious impact on equipment. Many

of the hundreds of trace compounds in landfill gas are corrosive. Considerable capital cost may be required to treat landfill gas to reduce trace constituent levels to those usually found in natural gas.

7. Pressure Requirements. Ideally, the landfill gas developer can deliver gas to the medium-Btu user at the minimum pressure necessary for transmission. In some cases, however, high pressure requirements at the point of use may exist, thus necessitating additional compression of the landfill gas to pressures as high as in large natural gas pipelines.

8. Price Paid. The largest determinant of medium-Btu landfill gas use viability is the price paid by the user. Typically this price is a function of the current natural gas cost. Some discounts will have to be offered compared to natural gas prices in order to encourage the user to convert to LFG. These discounts have ranged between 10 and 40 percent, and can be more depending upon the burden of retrofit placed on the user.

Natural gas prices were quite high several years ago, thus creating additional impetus for development of medium-Btu landfill gas projects. In 1985 and 1986, natural gas prices have decreased to record low levels, resulting in a decreased economic viability for medium-Btu uses.

Electrical Generation

A second use for landfill gas is electrical generation. In this case, nominal removal of particulates and moisture may be performed. The gas is used as the fuel for internal combustion engines connected to a generator to produce electricity. Gas turbines have been used for several electrical generation projects at exceptionally large landfills. The electricity is usually sold to the local electric utility. Under the Public Utilities Regulatory Policy Act (PURPA), electric utilities are required to buy electricity from small generators such as those found at landfill gas sites, and pay the "avoided cost," which is essentially the utility's cost of generating the next increment of electricity. A separate set of criteria impacts the economic viability of electric generating projects. These may include:

1. Proximity to Connection Points. This is usually not a significant problem, as electric lines are often close to the landfill. The only question then is whether they are of adequate capacity.
2. Access to Connection Point. In certain cases, transmission for long distances may be necessary. Access across adjoining properties and acquisition of appropriate right-of-way may then be required.
3. Switching Requirements. A large cost associated with electric generating facilities is the specialized switchgear needed to connect to the local utility. These are highly variable and generally

depend upon the requirements of the specific utility and the conditions at the point of connection.

4. Utility Cooperation. Although PURPA requires utilities to purchase electricity from small generators, some electric utilities are more cooperative than others. Obviously, good cooperation can speed up the contract execution process, and allow for prompt project start-up.

5. Avoided Cost Paid. Utilities usually publish schedules of current avoided cost and estimated future escalations, which are highly variable. Avoided costs are quite high in New York, the New England States, and throughout California, but are much lower in the Midwest and South since the majority of electric power is derived from burning coal. Thus, more electric generation projects have been initiated in New York City and California than elsewhere.

High-Btu Uses

High-Btu gas is the third application for landfill gas use to be discussed. For these uses, LFG is processed to remove the carbon dioxide. The resultant gas is similar to natural gas in terms of energy content. Considerations impacting the economic viability of these projects are:

1. Available Pipeline of Adequate Capacity. Unlike electric lines that are usually convenient and accessible, large natural gas pipelines of sufficient capacity near to a landfill site are not commonplace.

2. Utility Cooperation. Sale of an upgraded high-Btu gas may be made either to the local natural gas utility, or perhaps to a major pipeline company. Unlike electric generation where utility companies are required by law to purchase the electricity, there is no requirement in most jurisdictions for gas utilities or pipeline companies to purchase high-Btu gas.

3. Ease of Transmission. Transmission to the point of pipeline injection can be costly and acquisition of right-of-way may be both expensive and time consuming. The same transmission considerations applicable to medium-Btu use apply to high-Btu use.

4. Pressurization Requirements. Large natural gas pipelines typically operate at high pressures, but natural gas lines operated by small utilities usually are not operated at such high pressures. In either instance, however, some pressurization of the gas will be required, possibly adding considerable cost.

5. Quality Requirements. Different gas utility and pipeline companies have varying criteria for acceptance of gas, which usually relate to moisture content, energy (Btu) content, oxygen content, and trace constituent levels.

6. Price Paid. In order to secure the cooperation of the gas utility, a discount on the current price paid by the utility for natural gas will likely be

necessary. Since natural gas costs are currently quite low, contracts negotiated during 1985 and 1986 are generally not favorable for the gas developer.

REFERENCES

1. SCS Engineers. Landfill Gas Resource, Evaluation, and Development Guidebook. Gas Research Institute. Report No. 85/0250. November 1985.

SECTION 13

DECISION-MAKERS' GUIDE

When a landfill is considered for gas recovery, a three-step process is appropriate. The first step involves comparing landfill site characteristics against various minimum acceptable criteria. If the characteristics exceed these minimum values, a more detailed feasibility study can then be performed using more site specifics and formulas for gas recovery quantities, revenues, and costs. Finally, a field testing program should be performed. A testing program will confirm the rules-of-thumb utilized in the first two steps and provide data that can be used to design and construct the well field.

MINIMUM CRITERIA

The first assessment consists of comparing basic landfill characteristics against selected minimum acceptable criteria. These include:

1. In-Place Waste Quantity. A value generally accepted in the industry is that a landfill must have in excess of 1 million tons of refuse in place.(1) Where conditions for gas utilization are ideal, exceptions to this minimum value may exist. However, in many cases, landfills smaller than 1 million tons have proven to be uneconomical.
2. Operational Status. Organic material has a limited gas production lifetime. The volume of gas generation initially will increase, and then start to decrease.

Within a period of time (10 to 30 years), the rate of gas generation will decrease to a point where the cost of operating the recovery system exceeds revenues. It is best that the site being considered either be operational or have been recently closed.

3. Depth. For gas recovery to be economically viable, the minimum landfill depth should be about 40 ft.(1) Recovery from a landfill shallower than this is marginal even when the total waste quantity is in excess of 1 million tons.

4. Area. The landfill should have at least 40 acres of fill area.(1) Most landfills with more than 1 million tons meet this criterion.

If a site passes all of the above criteria, a more detailed feasibility investigation should be performed. If the site fails only one of the criteria and there are other strong indications of viable recovery, an expert in LFG recovery should be consulted to assess recovery feasibility. An estimated 10 to 25 percent of currently active landfills should pass the test for minimum criteria. For those sites, the more detailed analysis below is appropriate.

REVENUE VS. COST COMPARISON

The second more detailed assessment of LFG recovery viability consists of estimating gas quantities and potential revenues, estimating capital and operation and maintenance (O&M) costs for collection and utilization, and comparing revenues against costs to determine profitability.

In [illegible] gas quantities, these values can be used:

1. Generation Rate. Gas generation rates can vary from 0.08 to 0.28 cu. ft. per. lb. of refuse per yr.(2) A typical value is 0.15 cu. ft. per. lb. per year.(3) Note that this figure is for total generation, and that collection will be a percentage of this value. In determining the total number of pounds of waste at a landfill, some assumption about landfill density must be used; densities may range from 600 to 1,500 lb. per cu. yd.(4) If site densities are not known, a figure of 1,000 lb. per cu. yd. is a commonly used assumption.
2. Collection Rate. Not all landfill gas generated can be collected. Collection efficiency is a function of the landfill geometry, the layout, and design of the collection system. Typical collection efficiencies range from 25 to 75 percent of the gas generated.(3) An average of 50 percent is reasonable for estimating purposes.(4)
3. Energy Content. Methane concentrations in LFG average about 50 percent; under conditions of collection, this value may change.(4) Typical methane content of LFG ranges from 40 to 60 percent, with equivalent energy values of 400 to 600 Btu per cu. ft.(1) In the absence of other information, 500 Btu per cu. ft. is a reasonable assumption.
4. Operational Downtime. Further reductions to derive ultimate gas collection volumes should be applied to

account for downtime of the collection and recovery system. Values typically range from 5 to 15 percent, depending upon the quality of the collection system, the degree of sophistication and the level of maintenance. For estimating purposes, the landfill gas recovery industry uses values of 5 percent for medium-Btu systems, 10 percent for electric generating plants, and 15 percent for high-Btu processing plants.(2)

5. Gas Revenue Rates. Sale prices for medium- and high-Btu gas vary as a function of prevailing local prices for natural gas. Over the past several years, these rates have ranged from a low of about $2 per million Btu, to a high of $6 per million Btu. In order to compete with natural gas, a landfill gas developer must offer a discount on natural gas prices to the potential user. These discounts are typically from 10 and 40 percent. Local gas utilities can provide data on their rates and a discount factor applied. The discount should be directly proportional to the degree of retrofitting required by the gas user.

6. Electricity Revenue Rates. Under PURPA, electric utilities are required to buy electricity from small generators, such as landfill gas recovery facilities. The value paid is the avoided cost, and may range from $0.01 to $0.10 per kwh. The local electric utility's avoided cost must be obtained and converted to a price per Btu. A typical conversion factor used is 17,500 Btu per kwh.(2)

7. <u>Energy Escalators</u>. An escalator from current rates to rates in the initial year of operation should be used in the feasibility analysis. The cost for electricity can be expected to escalate in the future. In certain cases, electric utilities may be able to provide projections of future avoided costs. In other instances, escalations have to be assumed. Values between 5 and 10 percent per year are often used. (2)

   Similarly, escalation rates of 5 to 10 percent for natural gas prices have been used. With the reduction in natural gas prices over the past two years, cost escalation predictions may not be reliable.

Costs for gas recovery and utilization systems are highly variable depending upon site location, degree of sophistication, useful life of equipment, site conditions, and other factors. Despite such variability, there has been some agreement within the industry on general rules-of-thumb for calculating capital and O&M costs for gas recovery facilities. These formulas have been presented in a document prepared for the U.S. Department of Energy.(2) In this document, capital costs in 1982 for various systems were described as follows:

1. <u>Medium-Btu Facilities</u>. Capital cost = \$(0.2)(cu. ft. per day) + \$1,000,000. This formula is valid for an operating range of 2 to 20 million cu. ft. per day of input gas.

2. <u>High-Btu Facilities</u>. Capital cost = \$(0.7)(cu. ft. per day) + \$1,000,000. This formula is valid for an operating range of 2 to 10 million cu. ft. per day of input gas.

3. <u>Electrical Generating Facilities</u>. Capital cost = \$(1.0)(cu. ft. per day) + \$1,000,000. This formula is valid for an operating range of 2 to 10 million cu. ft. per day of input gas.

O&M costs are also quite variable, depending on plant technology, labor requirements, and site factors. For example, excessive landfill settlement may damage the collection system, and necessitate frequent repairs or replacement. First year O&M costs are estimated to be about 10 percent of capital cost.(2) Some escalation in the O&M dollar amount thereafter to allow for general inflation is appropriate. In addition, some non-routine O&M expenditures at 5 or 10 year intervals may be necessary for repair or replacement of process and blower facilities. A summary of expected capital and O&M costs for facilities of various sizes based on these formulas has been included as Exhibit 13-1.

Taxes can have a significant impact on the economic viability of a gas recovery and utilization project when private parties are the developers. Historically, investment tax credit and energy tax credits have been advantageous to the development of many projects, turning otherwise non-profitable or marginal facilities into economically viable programs. However, tax benefits vary widely depending on the nature of the individual project, and the tax status of the developing organization.

For 1987 only, qualifying LFG recovery projects can claim a 10% tax credit. This credit is referred to as an Energy Tax Credit or Business Energy Credit and is described in Internal Revenue Code (IRC) Section 46(b)(2)(A). This credit is eliminated after 1987.(5)

An Alternate Energy Production Credit is also available to LFG recovery projects and is described in IRC Section 29(a). It provides for a tax credit worth (in 1986 dollars) approximately $4.50 per barrel of oil equivalent that an LFG recovery project displaces. This credit applies to LFG facilities that were in service after 1979 and will include facilities in service before January 1, 1990. Credits are available through the year 2000, and are variable as are described in the IRS Code.(5)

The estimated revenues and costs should be calculated on an annual basis and compared. Capital costs should be annualized and include debt service using interest rates and other costs appropriate to the situation. If the cost analysis does not show a break-even or profitable outlook, the concept of a gas recovery and utilization facility should be abandoned unless there are extenuating circumstances; e.g., a requirement to provide odor or migration control.

FIELD TEST

If the cost analysis is favorable, a field test should be conducted to confirm the estimates related to gas recovery. Specialized equipment and experienced LFG engineers are required

EXHIBIT 13-1

TYPICAL CAPITAL AND O&M COSTS

Plant Capacity (LFG Inflow in mm cfd)	Medium-Btu End Use		Electric Generation End Use		High-Btu End Use	
	Capital Cost	First Year O&M Cost	Capital Cost	First Year O&M Cost	Capital Cost	First Year O&M Cost
2.5	$1,500,000	$150,000	$ 3,500,000	$ 350,000	$2,750,000	$275,000
5.0	2,000,000	200,000	6,000,000	600,000	4,500,000	450,000
7.5	2,500,000	250,000	8,500,000	850,000	6,250,000	625,000
10.0	3,000,000	300,000	11,000,000	1,200,000	8,000,000	800,000

[1] Four-foot earthen liner, leachate collection system, 40-acre site, 1,000,000 tons/2,000,000 cubic yards, 15-year site life.

[2] Five-foot clay liner (on-site clays), leachate collection system, 40-acre site, 1,000,000 tons/2,000,000 cubic yards, 15-year site life, 30-year long-term care period.

[3] Costs are in 1985 dollars.

*Source: Gleb, R., and E. Scaro. 1985. Cost Accounting for Landfill Design and Construction Past and Present. Waste Tech 1985 Proceedings, National Solid Waste Management Association, Washington, D.C.

REFERENCES

1. Johns Hopkins University Applied Physics Laboratory. Landfill Methane Utilization Technology Workbook. Prepared for U.S. Department of Energy, Division of Buildings and Community Systems. Report No. CPE-8101. February 1981.

2. Argonne National Laboratory. Methane from Landfills: Preliminary Assessment Workbook. Prepared for U.S. Department of Energy, Office of Renewable Technology. Report No. ANL/CNSV-31. 1982.

3. Walsh, J.J., and R.E. Zimmerman. Elements of a Landfill Gas Utilization Feasibility Study. Report of the Landfill Gas Feasibility Study Subcommittee of the Landfill Gas Committee, Governmental Refuse Collection and Disposal Association. Silver Spring, Maryland. April 1984.

4. Lockman and Associates, Inc. Recovery, Processing, and Utilization of Gas from Sanitary Landfills. Prepared for U.S. Environmental Protection Agency. No. EPA-600/2-79-001. February 1979.

5. Internal Revenue Code. Washington, D.C. 1986.

SECTION 14

SUMMARY AND CONCLUSIONS

Landfill gas can be either a hazard or a benefit at closed and operating landfills. Hazards are associated with the explosive potential of the methane content of LFG. Additionally, concerns have been raised (at least in California) about surface emissions of LFG from landfills and their contribution to air pollution. The gas is being recovered as an alternative fuel at several sites where the economics are favorable.

When organic matter decomposes in a sanitary landfill, it is transformed into a variety of simpler organic materials by the action of microorganisms abundant in solid waste. These processes produce principally methane and carbon dioxide. The rate of the LFG production is dependent on a number of site-specific factors, including the age of the landfill, moisture content and distribution, and solid waste composition and quantity.

LFG generation begins almost immediately upon burial and increases rapidly with steady generation beginning within several months to a year. Relatively steady generation may continue for 10 years or longer. Thereafter the generation rate decreases, but gas generation continues for many years.

Recovery of LFG for beneficial use is currently practiced at more than 50 locations nationwide with more than 40 other systems in the planning stages. The quantity, quality, and collectability of LFG, and the availability of markets are factors critical to the success of a LFG recovery project. Assuming that LFG markets are present, potential recovery sites are generally evaluated based on the following criteria:

- Amount of refuse -- The quantity of LFG produced depends first on the amount of refuse available for decomposition. For commercial applications, an LFG recovery site should have a minimum of roughly one million tons of refuse in place and an average depth of 40 feet.

- Refuse composition and moisture content -- Waste composition can limit both the total yield and rate of LFG production. In general, LFG production is stimulated by a waste having high percentage or readily decomposable organic materials (e.g., food and garden wastes).

- Age of the landfill -- As biodegradation of organic materials is completed, less LFG is produced (and eventually none is produced at all). Therefore, older disposal sites will produce less LFG because the rate of decomposition has decreased. Recovery sites should be recently closed, or preferably, have active fill life remaining.

Capital and O&M costs for LFG recovery systems can be quite high. Thus the right combination of site condition, gas volumes and market conditions must be present to make recovery attractive for financial reasons only. Capital costs will always be well over $1 million with O&M costs of more than 10 percent of capital costs occurring every year.

The recovery of gas via collection systems can help achieve the positive aspects of migration control, control of surface emissions, and recovery of an alternative fuel. Recovery systems withdrawing LFG can control migration and thus reduce the potential for explosions. Other types of control systems including pressure curtains and vent trenches do not reduce surface emissions and actually encourage them. Systems recovering LFG for energy also help control horizontal migration and surface emissions. However, no one system will optimally meet all three goals, as mentioned above.

State regulations exist and primarily focus on the control of LFG migration. However, both California and Washington have regulations that encourage or require the collection, rather then venting, of LFG. Thus in most parts of the country the recovery of LFG is based almost exclusively on the value of the gas as a fuel. Where it is profitable to recover LFG, it will be recovered. The control of gas migration is related to site-specific situations and is driven by safety considerations. This is true for both closed and operating landfills.

The recovery of LFG as fuel currently rests on economics. As more States, and possibly even the Federal government, move toward LFG regulation, recovery will become increasily attractive. As these regulations become more common, installation of recovery systems will become more popular for both closed and operating sites. In addition to the economic benefits, LFG recovery will aid in meeting landfill surface emission criteria and/or help control horizontal migration. The combination of positive and negative motivators (the value of the gas as a fuel and the regulations) may result in more sites with control systems.