IMPLEMENTATION GUIDE FOR LANDFILL GAS RECOVERY PROJECTS IN THE NORTHEAST

FINAL REPORT

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September 9, 1994
File No. 0292104

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SECTION 1

INTRODUCTION

This handbook has been prepared on behalf of the Northeast Regional Biomass Program, which is administrated by the CONEG Policy Research Center, Inc. The handbook is intended primarily to inform state and federal energy department policy makers, regulatory agencies, and public utility commissions (PUC) about the key issues regarding development of landfill gas (LFG)-to-energy projects in the Northeast and ways to overcome project impediments.

Other readers of this document will include municipal and private landfill owners, electric and gas utilities, and potential public and private LFG developers. The handbook provides them with information about LFG site development in terms of the required landfill characteristics, about LFG collection and utilization systems used, and about project economics, institutional factors, and regulatory issues.

BACKGROUND

Landfills produce LFG as organic materials decompose under anaerobic (without oxygen) conditions. LFG is composed of approximately equal parts of methane and carbon dioxide with trace concentrations of other gases, including non-methane organic compounds (NMOC). The combustibility of methane can be both an asset and a liability to a landfill owner — an asset when the gas becomes a source of energy recovered from LFG, and a liability when subsurface migration of LFG results in hazardous conditions. LFG can be used in place of conventional fossil fuels. The LFG heating value typically ranges from 400 to 600 Btus (British thermal units) per standard cubic foot (scf) which is approximately one half the heating value of natural gas.

The LFG recovery industry started in California in the early 1970s and spread from there. The first project was at the Palos Verdes Landfill in Los Angeles County, CA, where the extracted LFG was upgraded to pipeline quality gas. Numerous LFG-to-energy projects have been operating in California for upwards of 10 years. On the other hand, projects in the Northeast have been slow to get started with the majority of them having commenced operation in the last 5 years.

From the late 1970s until the mid-1980s, LFG recovery for use as an energy source was supported by favorable energy prices. From the late 1980s to the present, LFG developers have experienced lower energy prices, stiff competition, and additional regulation.

Using LFG as an alternative fuel source may again become attractive to developers and investors for several reasons. Increases in fossil fuel costs, government support of LFG-to-energy projects, and costs of complying with environmental regulations all play a role. For example, the cost of complying with Federal and state regulations for control of air emissions should make recovery of LFG more economically attractive because by selling the landfill byproduct (LFG), the landfill owner can offset a portion of the (required) pollution control cost.

PURPOSE OF THE HANDBOOK

The handbook has a twofold purpose; the first is to provide general background information for the decision-maker including definitions and characteristics, criteria for a successful project, barriers to success, and recommendations to overcome these barriers. The second is to examine candidate landfill sites in the Northeast for utilization projects and to evaluate them in terms of the criteria for successful projects.

This handbook informs government policy makers of the total energy potential available from LFG in the Northeast; provides information about LFG recovery that might influence state and federal energy policy; and encourages development of LFG recovery projects by providing ideas which could make development easier.

REPORT ORGANIZATION

This handbook is divided into the following sections:

- Section 2: State of the Landfill Gas Recovery Industry - describes the technical, economic, institutional and environmental aspects of LFG recovery projects.

- Section 3: Project Approach - describes how the data and information were gathered and the interview process that was used; it also discusses who was interviewed for this report, how the interviews were conducted, and how the information was compiled.

- Section 4: Successful Project Criteria and Impediments to LFG Utilization - presents criteria for successful projects, barriers, and recommendations to overcome the barriers.

- Section 5: Identification of Candidate Northeast Landfills for LFG Utilization - identifies candidate landfill sites in the Northeast which have not been developed to-date and appear to be large enough to support a project.

- Section 6: Landfill Gas Models - presents a LFG generation and economic model for preliminary modeling of candidate sites.

- Section 7: Areas for Future Study.

SECTION 2

STATE OF THE LANDFILL GAS RECOVERY INDUSTRY

INTRODUCTION

The purpose of this section is to summarize the technical, economic, institutional and environmental aspects of LFG recovery projects. It is aimed at an audience with limited knowledge of solid waste landfills and LFG recovery. The section is organized as follows:

- **LFG Generation** — information on how LFG is generated, its composition, and why it must be managed.

- **LFG Collection Methods** — techniques for extraction of LFG from a landfill.

- **LFG Utilization Methods** — discussion of the major commercial uses of LFG including:

  – Direct use as boiler fuel or for space heating;
  – Electrical generation using engine generators or gas turbines; and
  – Upgrading to pipeline-quality gas.

- **Economics** - presents the range of capital and operating costs of existing projects, revenue ranges, and summary of new federal incentive programs.

- **Environmental Issues** - summarizes existing and proposed federal regulations and state requirements to control emissions from landfills.

- **Institutional Issues** - summarizes project development options, identifies the major LFG recovery developers, and identifies project impediments.

LFG GENERATION

Landfills produce LFG as organic materials decompose under anaerobic conditions. LFG is composed of approximately equal parts of methane and carbon dioxide with trace concentrations of non-methane organic compounds (NMOC). Methane is a combustible gas that forms an explosive mixture when present in concentrations between 5 and 15 percent by volume in air. The combustibility of methane can be both an asset and a liability to a landfill owner — an asset when the gas becomes a source of energy recovered from LFG, and a liability in terms of hazardous conditions caused by subsurface migration of LFG. The typical LFG components and concentrations are listed in Exhibit 2-1.

EXHIBIT 2-1. TYPICAL LANDFILL GAS CONSTITUENTS FOR RECOVERY PROJECTS

Component	Concentration Range (%)
Methane	40 - 60
Carbon Dioxide	30 - 50
Oxygen	0 - 2
Nitrogen	0 - 10
Hydrogen Sulfide	Trace levels
Non-Methane Organic Compounds (NMOC)	Trace levels

Oxygen and nitrogen levels are indicators of air intrusion through the landfill surface or LFG collection system and must be minimized for economic recovery of the LFG. The environmental and health concerns associated with municipal solid waste (MSW) landfills have been well documented. In the United States, the Environmental Protection Agency (EPA) has documented 40 cases of LFG migration resulting in explosions and fires, of which 10 cases resulted in injuries and deaths [USEPA, 1991]. Methane emissions also are a concern because of their potential contribution to global warming. Landfills are a significant source of methane, ranking third in anthropogenic sources after rice paddies and ruminants [Thorneloe, 1992].

Another concern with LFG emissions is the contribution of NMOCs to tropospheric ozone which affects human health and vegetation. NMOCs include several compounds that are known carcinogens to humans. The EPA has estimated that roughly 1 percent of the NMOC emissions from stationary sources in the U.S. are emitted by municipal solid waste (MSW) landfills [Thorneloe, 1992].

On the positive side, LFG can be utilized as a fuel to offset the use of conventional fossil fuels. The heating value typically ranges from 400 to 600 Btus (British thermal units) per standard cubic foot (scf) which is approximately one half the heating value of natural gas. The approximate equivalents of LFG to other common fuels are presented in Exhibit 2-2.

EXHIBIT 2-2. FUEL EQUIVALENTS OF LANDFILL GAS
(LFG with 50 percent methane)

Fuel	Equivalents (per 1,000 cubic feet of LFG)
Natural Gas	500 cubic feet
Propane	5.5 gallons
Butane	4.9 gallons
Gasoline	3.9 gallons
No. 2 Fuel Oil	3.6 gallons
Bituminous Coal	37 pounds
Medium-dry Wood	83 pounds

Exhibit 2-2. (continued)

Source: Georgia Tech, 1988.

LFG COLLECTION METHODS

LFG collection systems can be categorized into two basic types — vertical wells and horizontal trenches.

Vertical Well System

The most common system for LFG collection is the vertical well system. The wells typically consist of 24- to 36-inch-diameter borings. Occasionally, small-diameter borings (e.g., 12 and 18 inches) are used. Two- to 8-inch- diameter pipes (typically polyvinyl chloride [PVC] or high-density polyethylene [HDPE]) are placed in the borings, and the borings are backfilled with 1-inch-diameter, or larger, stone. The pipe is perforated in the lower section where the LFG is collected; solid pipe is used near the surface to prevent air infiltration.

Typical well depths range from 25 to 75 feet, but may exceed 100 feet, depending on landfill depth. Wells are typically drilled to the depth of the liquid level in the landfill, or to approximately 75 percent of the landfill depth, whichever is less. Well drilling requires careful monitoring to avoid affecting the bottom of the landfill. The well spacing is dependent upon landfill characteristics (e.g., landfill depths, refuse type, compaction rates, cover materials, etc.). Well spacing generally ranges from 50 to 300 feet [EPA, 1991].

The vertical well system uses a blower or compressor to extract the LFG under vacuum from the landfill through the piping network. Exhibit 2-3 shows the major components of a LFG collection system.

Horizontal Trench System

Horizontal trenches may be installed instead of or in combination with vertical wells to collect LFG. Trenches consist of an excavated trench (similar to a pipeline trench) which is backfilled with permeable gravel. Perforated, slotted, or alternating diameters of pipe are installed in the trench. Additional lifts of refuse are placed on top of the trench.

Horizontal trenches are less expensive then vertical wells and are particularly suitable for installation in active filling areas.. They are not as much in the way of and are not as likely to be destroyed by subsequent filling.

EXHIBIT 2-3. LFG RECOVERY SYSTEM WELLFIELD LAYOUT

Combined Leachate/LFG Collection Systems

Several landfill sites have installed combined extraction wells for both LFG and leachate collection. Leachate is collected from the lower section of the screened well casing, using a submersible pump (pneumatic or electric). LFG is collected from a separate well pipe or from a perforated section above the well screen. The leachate is transmitted to the leachate storage or treatment system and the LFG to the recovery facility. The leachate and LFG may be separately transmitted or combined in one piping system. These combined systems are relatively new techniques and their long-term performance have not been well documented.

Cover Venting Systems

Some states are requiring LFG venting layers to be installed as part of the final cover system for the landfill. The vent layers often consist of 1 foot of sand overlain by a low- permeability cover system (e.g., clay and/or a membrane). LFG is vented to the atmosphere through vent pipes spaced at a frequency of one vent per acre. The purpose of the venting system is to provide a means to relieve LFG pressures under the cap. Several sites are considering connecting their venting systems to an active recovery system.

Typical Landfill Characteristics

LFG recovery projects have been installed successfully on both large and small landfills. The range of landfill characteristics (in terms of size parameters) for the landfills included in the Government Advisory Associates (GAA) LFG recovery system survey are presented in Exhibit 2-4.

EXHIBIT 2-4. LANDFILL CHARACTERISTICS AT LFG RECOVERY FACILITIES

Component	Minimum	Mean	Maximum
Total Landfill Acreage (ac)	20	207	3,000
Acreage Devoted to LFG Recovery (ac)	4	106	570
Average Depth of Fill (ft)	11	84	200
In-Place Refuse Tonnage (tons)	50,000	7,000,000	50,000,000
Number of Collection Wells (ea)	7	69	1,200

Source: GAA Yearbook, 1992.

Construction costs for LFG collection systems are dependent upon the number of wells, the spacing of wells, drilling depths, and site conditions. The largest variable is the drilling costs which can range from $30/ft to over $100/ft. An industry rule-of-thumb cost for the complete collection system, wells, headers and condensate traps is $10,000 per acre.

LFG UTILIZATION TECHNOLOGIES

Overview

Several surveys of operating and planned LFG recovery projects have been conducted in recent years. Survey results have varied significantly, due to the relatively long project development times, small project sizes, and large number of small developers. Approximately 100 to 120 LFG energy recovery facilities are estimated to be operating in the U.S. Additional projects are in

various stages of development. A listing of the 39 identified operating LFG projects within the 11 Northeast states is presented in Exhibit 2-5.

The LFG energy market is the major factor that influences the viability of LFG recovery. Existing and potential uses of LFG generally fall into one of the categories presented in Exhibit 2-6. These uses are discussed below.

EXHIBIT 2-6. LFG ENERGY APPLICATIONS

Current Applications	Degree of Use
Direct Use	
Space Heating (and Cooling)	Limited
Industrial Process Heat	Limited
Boiler Fuel	Moderate
Electrical Generation	
Internal Combustion Engines	Most Common
Gas Turbines	Common
Steam Turbines	Limited
Upgrade to High Btu	
Pipeline-Quality Natural Gas	Moderate
Potential Future Applications	
Compressed Methane for Vehicle Fuel	
Electrical Generation: Fuel Cells	
Synfuel or Chemical Feedstock	

Source: Augenstein, 1992.

Current Applications

Direct Use Application--

The options for direct use of the medium heating value LFG (~500 Btu/cf) include use as a boiler fuel, space heating and cooling, and industrial heating/cofiring applications. The most common use is as boiler fuel to produce steam or hot water. This option is a particularly attractive since conventional equipment can be used with limited modification. In addition, boilers tend to be less sensitive to LFG trace constituents, and consequently less gas cleanup is required compared to other alternatives [Thorneloe, 1992].

Because landfills decompose and generate LFG continuously and because LFG storage is not economically practical, a continuous use of LFG normally is required. Ideally, the user

EXHIBIT 2-5. LFG RECOVERY PROJECTS IN THE NORTHEAST

EXHIBIT 2-5 (Continued)

will be a single customer with a large demand, preferably 24 hours/day, 7 days/week year-round operation. Additionally, the user must be relatively nearby: less than 1 to 2 miles is considered desirable.

Other medium Btu options include industrial applications such as kiln operations, lumber drying, and cement manufacturing. An advantage of many industrial applications is that fuel is required continuously, 24 hours per day. LFG also can be used as a supplemental fuel that meets a portion of the total demand. LFG to produce space heating is limited primarily due to piping costs and difficulty in matching up the LFG energy output with nearby user needs. Space heating loads tend to be variable, both during the day and by season [Thorneloe, 1992].

The specifications for the gas vary by site and typically include the following:

- Minimum heating value (400 Btu/scf or higher);
- Delivery pressure, minimum temperature;
- Sulfur limits; and
- Maximum water content (a dry gas is desired).

Electrical Generation--

Approximately 75 percent of the LFG recovery facilities in the U.S. generate electricity which is sold to a local electric utility company. A few of these electricity generation facilities use a fraction of the electricity on site. Of the operating electrical generation projects in the United States, the 61 projects that responded to the survey produce an estimated 344 MW (megawatts) of power. A typical flow schematic for an LFG recovery project with electrical generation is presented in Exhibit 2-7.

Internal combustion (IC) engines used to generate electricity are most commonly "lean burn" turbocharged designs that burn fuel with excess air. Less commonly, IC engines may be "naturally aspirated" without turbocharging. The naturally aspirated engines are easier to operate because they are less complex, but they have reduced power output and higher emissions. When operated on LFG, engine power ratings are commonly reduced by 5 to 15 percent compared to operation on natural gas. The overall heat rate (after reduction for parasitic loads) ranges from 11,000 to 14,000 Btus of LFG per kilowatt hour (kwh).

IC engines drive generators to produce electrical power that is typically sold to the local electric utility. Four manufacturers — Caterpillar, Waukesha, Cooper-Superior, and Cummings — are the primary suppliers of these engineers. The IC engines have been specially designed for LFG applications.

Gas turbines used to generate electricity at landfill sites take large quantities of atmospheric air, compress the air, burn fuel to heat the air, and then expand the air in the power turbine to develop shaft horsepower. This horsepower can be used to drive pumps, compressors, or electrical generators. Turbines should be operated at full capacity to optimize performance and limit operational problems [Thorneloe, 1992]. The turbines used at landfill sites are either Saturn or Centaur models manufactured by the Solar turbine division of Caterpillar. As of 1989, more than 30 turbines were in use at over 20 landfill sites [Augenstein, 1992].

EXHIBIT 2-7. LFG RECOVERY/UTILIZATION SCHEMATIC

Steam-electric turbines are used at several sites where the LFG is burned in a boiler to produce high-pressure steam, which drives a steam turbine to generate electricity. The largest LFG recovery project in the U.S. is the Puente Hills Energy Recovery from Gas (PERG) in Whittier, California. PERG has two Zurn Industries gas-fired steam generators, and a Fuji Electric turbine that generates approximately 50 MW of power [Valenti, 1992].

Upgrade to High Btu--

Seven sites in the U.S. upgrade LFG to pipeline quality natural gas. These projects generally were implemented in the early 1980s when gas prices on a heating-value basis were comparable with oil. These sites have an average LFG flow rate of 5 million scfd with a range from 1.1 to 9.5 million scfd [Thorneloe, 1992, GAA Yearbook, 1992].

High capital cost technology is required to purify the gas to pipeline quality by removing the water, hydrogen sulfide, chlorinated hydrocarbons, and other trace constituents as well as separating out the carbon dioxide (CO_2). The largest operator of facilities producing pipeline quality gas from LFG is GSF Energy, Inc., a subsidiary of Air Products and Chemicals, Inc. Low natural gas prices in the late 1980s caused several projects to cease operation, and continue to inhibit the development of new high-heating-value LFG projects in the U.S. [Thorneloe, 1992].

The high Btu gas must meet pipeline specifications that normally require the following [Koch, 1986]:

- A minimum heating value of 950 Btu/scf;
- Water levels less than 0.7 lbs of water/million scf;
- Hydrogen sulfide less than 1/4 grain/100 scf;
- Total sulfur less than 9 grains/100 scf;
- Interchangeable with natural gas (i.e., acceptable heating value, relative density, and oxygen level limits); and
- Contain no toxic, harmful, or foreign materials.

LFG can be upgraded commercially to pipeline standards by the following processes: absorption, adsorption, membrane separation, and cryogenic separation (low-temperature processing). Of these four technologies, the first three technologies have successful commercial applications using LFG. Cryogenic separation has not been applied commercially for LFG. A comprehensive review of these technologies can be found in Koch, 1986.

<u>Potential Future Applications</u>

Vehicular Fuels--

Vehicle fueling with compressed methane is of interest for both environmental (low emissions) and economic reasons. The technology for such fueling is advancing. Wastewater treatment plant digester gas has been used for this purpose at some sites in California. Using LFG would involve purification — possibly to near pipeline quality gas — and then compression of the purified gas for reduced-volume storage and for use on vehicles equipped with conversion kits. The most attractive use is for fleet vehicles, in particular refuse trucks, which would need to return frequently to the landfill where the gas is generated. Gas availability and economics both

dictate that the vehicle fleets should be large. This use of LFG has been investigated and tried on a small scale in a number of locations over the past decade. A demonstration project is underway at the Palos Verdes Landfill in Los Angeles County. Initial operational data is promising, however, more detailed cost/benefit analysis is needed.

Fuel Cells--

Fuel cells are a potentially attractive option for LFG because of the higher thermal efficiency (near 40 percent), availability to small and large landfills, and low byproduct emissions. Another advantage includes low maintenance costs because fuel cells have no moving parts. Hydrogen from the LFG is combined electrochemically with oxygen from the air to produce direct current (DC) electricity and water. Demonstration projects are currently being pursued by EPA (a 200 kw phosphoric acid fuel cell project) and the Electric Power Research Institute (a 2 MW molten carbonate fuel cell pilot project) [Augenstein, 1992; EPRI, 1992; Thorneloe, 1992].

Synthetic Liquid Fuels--

Technologies are available that potentially could convert LFG to liquid fuels. These include hydrocarbon production by the Fischer-Tropsch process, methanol synthesis by various routes, including chemical catalysis at high pressures; or by partial biological oxidation. The feasibility of most of these synfuel approaches have been examined for large-scale applications using feedstocks such as gas from coal. The first commercial application of this technology using LFG was initiated at a landfill site in Pueblo, Colorado. The project employs a process which re-forms the LFG at high temperatures prior to removal of CO_2. Products were to include diesel fuel, naphtha, and waxes [Augenstein, 1992; Fuelco, 1991]. The project was located at a landfill site too small to support the plant. The commercial viability of this process is unknown at this time.

ECONOMICS

<u>Public Utility Regulatory Policy Act (PURPA)</u>

The Public Utility Regulatory Policy Act (PURPA) of 1978 was a major factor in encouraging LFG energy projects. PURPA requires that electric utility companies purchase power that was generated (from LFG) at a price related to the costs that the utility company would incur to produce the same amount of power. Although this guarantees a purchaser for the power, the power sales revenues may be low if the utility company's avoided costs are low.

When considering sale of electricity to a utility, most of the negotiations fall under the tenants of PURPA. PURPA requirements include [Georgia Tech Research Institute, 1988]:

- Requiring the utility to buy all power from any qualifying facility,
- Exempting a cogenerator from utility commission regulations,
- Blocking utilities from charging excessive rates for backing up a cogenerator, and
- Exempting a cogenerator from the Public Utility Holding Company Act and other federal utility acts.

Cost Elements

The major capital cost elements as reported by an LFG developer for a 1 MW power plant are shown in Exhibit 2-8.

EXHIBIT 2-8. CAPITAL COST OF A 1 MW LFG ENERGY UTILIZATION PROJECT

Item	Range of Costs	Typical Cost	Percent
Collection System	$200,000 - $1,000,000	$ 200,000	13
Administrative: Fees, Planning, Legal, Environmental	$30,000 - $1,000,000	$ 30,000	2
Interconnect Cost	$20,000 - $500,000	$ 76,000	5
Generating Equipment	$500,000 - $2,000,000	$ 970,000	65
Contingency		$ 225,000	15
TOTAL	$850,000 - $4,500,000	$1,500,000	100

Source: Jansen, 1992.

LFG recovery projects have an estimated economic life of 10 years, or 20 years for dry climate projects (Southern California). Typical contracts with the landfill owners range from 10 to 30 years; some are longer. The economic life for debt service is often estimated at 10 years for the recovery of the investment.

Project Revenues

The following are ranges of project revenues for the sale of LFG.

Electricity--

Many states have special schedules for the purchase of power from small quantity generators. These schedules detail the contract terms, capacity and energy payment terms, adjustment factors, etc. The LFG developer may receive peak or off-peak rates for the "avoided cost" of electricity from qualifying facilities (QF).

- Energy payments or avoided cost — the cost for the fuel that the utility would incur to generate the electricity.
- Capacity payments — the pro-rated savings resulting from increased system capacity which would allow the utility to avoid or defer new capacity additions.

Electrical power sales rates for existing LFG facilities operating in the Northeast are presented in Exhibit 2-9. Unfortunately, potential new projects are unable to receive comparable rates.

EXHIBIT 2-9. ELECTRICITY REVENUES BY STATE (EXISTING PROJECTS)
(Cents/Kilowatt-Hour)

State	Minimum	Mean	Maximum
Maryland	4.00	6.10	8.20
New Hampshire	6.00	6.00	6.00
New Jersey	2.65	4.88	6.00
New York	4.49	6.00	6.50
Pennsylvania	5.50	5.88	6.25
Rhode Island	5.25	5.25	5.25
Vermont	5.00	5.00	5.00

Source: GAA Yearbook, 1992.

The average electric power rate in the Northeast is 5.76 cents/kwh, with a range of 2.65 to 8.20 cents/kwh. In 1992 nationwide, planned facilities had a mean electric power rate of 4.58 cents/kwh versus 6.18 cents/kwh for operating facilities. This trend shows that developers of new LFG recovery facilities are feeling the effects of the current low prices of fossil fuels.

Medium Btu Use--

Revenues are usually based on the prices of equivalent energy sources. Typical revenues range from 75 to 90 percent of the price on a Btu basis for the fuel replaced (usually natural gas or fuel oil).

Pipeline Quality Gas--

Revenues are based on the price for natural gas. The gas is often sold at 90 percent of the pipeline price. Several projects have set floor prices to limit the risk of fluctuating energy prices.

Royalties--

LFG developers often pay a royalty to the landfill owner if the developer does not own the landfill. In most cases, the royalty represents a percentage of the project revenues from the sale of electricity or gas. The mean royalty payments reported from the survey was 15.35 percent, with a range of 4.5 to 50 percent [GAA, 1992].

The industry trend is to significantly lower royalty payments due to the reduced sales revenues and the increased costs of environmental compliance. Royalties negotiated in 1991 to 1993 reportedly have been in the 0 to 10 percent range.

Federal Programs

The Energy Policy Act of 1992 included several provisions which may have a positive impact on the LFG recovery industry. Two programs are discussed below.

Section 29 — Credits for Producing Fuel from a Non-Conventional Source--

The Section 29 (Internal Revenue Code) tax credits were initiated in 1979. A $3.00 credit per barrel of oil equivalent (5.8 Million Btus) is available for the production and sale of certain qualified fuels to unrelated parties. The credit is adjusted each year for inflation (subject to limitation dependent upon the well head price of oil). The credit is phased out as the price per barrel of oil exceeds $29.50. The deadlines for having the facilities in service were extended in the Energy Policy Act through the year 1996.

The estimated value of the tax credits (for 1993) were:

- Approximately 97.9 cents per million Btus, or
- Approximately $490 per million cubic feet of LFG.

The current requirements for an LFG developer to qualify for the tax credits are to [Congressional Record, 1992]:

- Produce gas from biomass, or liquid, gaseous or solid synthetic fuels produced from coal (or lignite);
- Sell the gas to an unrelated party;
- Obtain a binding written contract by January 1, 1996;
- Place the facility in service before January 1, 1997; and
- Apply tax credits through the year 2007 for a facility placed in service after 1992. Existing facilities (those placed in service prior to 1993) may receive the tax credits through the year 2002.

This availability of tax credits usually results in a second or third party being brought into the project. The tax credit is only available if the gas which is produced is sold to an "unrelated party" and is only of benefit if the producer can use the tax credits. [Pierce, 1992]. With this tax credit extension, a strong economic incentive exists for the future development of LFG utilization projects.

Section 1212 - Renewable Energy Production Incentives--

A "Renewable Energy Production Incentive" program also is included in the Energy Policy Act. This program offers a 1.5 cents/kwh payment (adjusted for inflation) to owners/operators who produce electricity from solar, wind, biomass, or geothermal sources at qualifying projects. The program will be in effect over a 10-year period and is subject to appropriations by Congress and Department of Energy (DOE).

To qualify for the program the owner/operator must [Congressional Record, 1992]:

- Generate electricity from solar, wind, biomass, or geothermal sources (burning municipal solid waste for energy is not included);
- Be a public entity or nonprofit electric cooperative;
- Use the facility for the first time in 1993 or later (excludes existing facilities); and
- Petition DOE for payments.

The Energy Policy Act only authorized this program for the first three years. Congress will need to appropriate the money to get this program started. The LFG recovery industry is monitoring Congressional and DOE activities to see how the program will be funded and implemented (including whether biomass will be defined to include LFG). DOE proposed a draft rule in May 1994 which outlined many of the program elements. A final rule is expected this in late 1994.

Proposed Btu Tax--

The Administration had proposed a broad-based energy tax to help reduce the federal government's deficit and advance three energy goals: reduction of environmental damage from fossil fuels, promote energy conservation, and reduce dependence on foreign sources of energy.

The proposed tax rate on coal and natural gas was $0.257/million Btus with oil being taxed at a rate of $0.599/million Btus. Biomass, including LFG, wood waste, and bagasse (sugar cane biomass), were to be exempted as of the April 1, 1993 version of the Department of the Treasury's proposal [Department of the Treasury, 1993].

This tax bill was defeated by the Senate in the summer of 1993, an unfortunate event for LFG and other renewable energy fuels.

ENVIRONMENTAL ISSUES

<u>Air Emissions</u>

LFG recovery facilities are subject to their state's air emission regulations. The lean-burn IC engines are often used in non-attainment areas where NO_x and CO emissions are of concern.

The reduction of permitted emission levels (e.g., from 250 to 25 tons/year for Nox) resulting from the Clean Air Act will have a profound impact on future facilities. Facilities in non-attainment areas with low emission limits may have to modify the engines and/or install additional equipment to control emissions.

<u>Subtitle D</u>

EPA promulgated regulations for the management of municipal solid waste landfills (referred to as Subtitle D) on October 9, 1991. These regulations have several provisions for the management of LFG. LFG monitoring is required in on-site buildings and along the site perimeter throughout the landfill's active filling and post-closure periods. Landfills must have such monitoring programs in place by October 9, 1993, which is the date Subtitle D goes into effect. Monitoring programs must show that methane concentrations are below the following limits:

- Facility structures may not exceed 25 percent of the lower explosive limit (LEL) (1.25 percent gas), and

- Site perimeter may not exceed 100 percent LEL (5 percent gas).

If methane concentrations exceed these limits, controls are required. Control may consist of passive or active LFG collection systems to protect facilities and prevent off-site LFG migration. Collected LFG is sometimes passively vented, but often is flared. The installation of active collection systems by the landfill owner may improve the economics of energy utilization projects for the LFG developer.

Clean Air Act - New Source Performance Standards

Overview--

Under the Clean Air Act Amendment, the EPA has proposed Emissions Guidelines for existing landfills and New Source Performance Standards (NSPS) for new landfills to control LFG emissions. The proposed rule and guidelines were announced on May 30, 1991, with the final rule expected in late-1994. This rule applies to landfills which received MSW after November 8, 1987 and have over 110,000 tons in place. The NSPS presents a three-tiered approach for assessing whether emission controls are required. If the landfill emits in excess of 167 tons of non-methane organic compounds (NMOCs) per year, controls are required. The tiers begin with desktop calculations to estimate air emissions, and then continue with field sampling and gas flow testing [EPA, 1991].

In March 1994, EPA recommended several important changes to the proposed rule. The landfill exemption design capacity would be increased from 110,000 tons to 1,100,000 tons. The NMOC emission rate requiring controls would be reduced from 167 tons of NMOCs to 56 tons. The default parameters for NMOC modeling also would be changed.

If the tests show that a landfill exceeds the emission limits, a LFG control system must be installed and operated for at least 15 years. The rule specifies reporting and operational requirements for the control system.

The NSPS require at least 98 percent destruction efficiency of NMOCs collected. The required destruction levels can be achieved by control devices including:

- Open flares,
- Enclosed ground flares,
- Internal combustion engines,
- Boilers,
- Gas turbines,
- Incinerators, and
- High Btu gas processing systems where vent streams are controlled.

The EPA Preamble encourages energy recovery of the LFG versus the use of flares as control devices.

Impact on LFG Recovery--

If the NSPS are implemented, an estimated 621 landfills would be required to control LFG emissions [EPA, 1991]. Potential impacts to LFG recovery feasibility include:

- The cost of the LFG collection systems may be borne by the landfill owner, thereby potentially reducing the capital cost of the recovery system.

- Uncertainties and inaccuracies in estimating LFG recovery rates could be reduced prior to implementing a utilization project.

LFG Condensate Management

LFG condensate forms as water and other vapors condense out of the gas stream due to temperature and pressure changes within the collection system. Condensate management can be a problem in LFG collection system operations. The condensate must be removed prior to utilization of the LFG in combustion equipment.

LFG condensate collection techniques include:

- **Direct Draining into the Landfill** — If permitted by regulation, condensate collected in traps at low points in the wellfield can drain directly into the landfill. Subtitle D specifically allows this for lined landfills with leachate collection systems.

- **Centralized Collection** — At some sites, LFG condensate is not permitted to drain into the landfill. Instead, the condensate is either collected by pumper truck at enlarged condensate traps in the wellfield and hauled to a sewage treatment plant, or a separate condensate collection system (with pumps at the condensate traps) is constructed.

- **Condensate Removal** — Condensate removed at the blower station/utilization plant typically is discharged or treated as follows:

  — Direct discharge to the leachate collection system or a sanitary sewer; or

  — Pre-treatment prior to discharge to the sewer if required by the publicly owned treatment works (POTW).

INSTITUTIONAL ISSUES

Project Ownership

On many projects, the owner of the landfill and operator of the LFG recovery project are separate entities. Project ownership summaries from the 1991-1992 GAA Yearbook are presented below.

Landfill Ownership--

Of the surveyed LFG recovery projects, 51 percent of the facilities are located at landfills owned and operated by the public sector (i.e., counties, cities, public authorities, etc.). Private firms own and operate approximately 43 percent of the landfill sites. Of the remaining projects, 4

percent are at publicly owned and privately operated landfills, and 2 percent are at privately owned and publicly operated landfills [GAA, 1992].

LFG System Ownership--

As shown on Exhibit 2-10, 75 percent of the LFG collection systems are owned by the private sector, and 80 percent of the processing systems are owned by the private sector. This illustrates the high level of private involvement in the projects, with the utilization of the Section 29 tax credits being a driving force.

EXHIBIT 2-10. OWNERS OF LFG RECOVERY SYSTEMS

Owner	LFG Collection System	LFG Processing System
Private Sector	75.6%	80.0%
Joint Ventures of Private Firms	5.8%	6.9%
Public Authorities	5.8%	6.2%
City/Town/Township	5.8%	2.8%
Counties	5.8%	2.8%
Federal Government	0.6%	0.7%
Joint Public/Private Sector Owner	0.6%	0.7%
TOTAL	100%	100%

Source: GAA Yearbook 1992.

<u>LFG Developers</u>

Much of the development of LFG recovery projects has been performed by relatively small energy development companies (with the exception of Waste Management, Air Products, BFI, and Laidlaw). The market share of the developers in the nation and Northeast region for existing and planned projects is presented in Exhibit 2-11.

Exhibit 2-11. (continued)

EXHIBIT 2-11. LFG DEVELOPER'S MARKET SHARE
(Existing and Planned Projects)

LFG Developer	Total Projects Nationwide	Total Projects Northeast
Waste Management of North America	32	9
Air Products, Inc.	10	2
O'Brien Energy Systems, Inc.	10	7
Pacific Energy	10	0
Laidlaw Gas Recovery Systems	7	1
Cambrian Energy Systems, Inc.	5	0
Energy Tactics, Inc.	5	6
Los Angles County Sanitation Districts	5	0
Solar Turbines/Caterpillar Capital	5	0
Browning-Ferris Industries	8	4
Michigan Cogeneration Systems	4	0
Gas Resources Corp.	3	0
Other Miscellaneous Developers	57	26
TOTAL	161	55

Source: GAA Yearbook, 1992; SCS Engineers, 1993.

Financing Mechanisms

The methods used to finance LFG recovery projects are presented in Exhibit 2-12. As shown, private investment or equity is the major mechanism being utilized (84 percent of the projects).

EXHIBIT 2-12. FINANCING MECHANISMS FOR LFG RECOVERY FACILITIES

Financing Mechanism	Number of Facilities	Percent
Private Investment or Equity	127	84.1
County or Authority Revenues	8	5.3
City or Municipal Revenues	7	4.6
Leverage Lease or Bank Lease	5	3.3
Federal Grant	3	2.0
General Obligation Bonds	3	2.0

Exhibit 2-12. (continued)

Financing Mechanism	Number of Facilities	Percent
Revenue Bonds	3	2.0
Federal Revenues	1	0.7
Industrial Development Revenue Bonds	1	0.7
State Loan or Loan Guarantee	1	0.7
Other Mechanism	5	3.3

Source: GAA Yearbook, 1992.

Project Impediments

Historically, the primary impediments to LFG recovery project implementation have been:

- Difficulties and delays in negotiating power sales agreements with electric utility companies and other end users.
- Undercapitalization of LFG developers.
- Overestimation of the LFG yield. Attributed to both overly-optimistic estimates of the volume of LFG that can be continuously extracted from a landfill, and inadequate well field construction and operation and maintenance practices.
- Lack of interest, time, or know-how in developing an LFG recovery system at landfills.
- Delays and difficulties in obtaining environmental permits.

SECTION 3

PROJECT APPROACH

INTRODUCTION

The LFG recovery industry has evolved over the past 20 years, accumulating substantial experience and knowledge. Unfortunately, much of this information is scattered among owners, developers, and engineers, still leaving some economic, regulatory and institutional concerns to be addressed, if the industry is to advance.

One objective of this project was to define what constitutes a successful or unsuccessful project. To do this, a survey was conducted of public and private LFG developers, owners and operators of landfills and LFG recovery projects, financial institutions, and energy users/purchasers. The survey was based on telephone interviews with representatives from each of these groups; the interviews were conducted after research of available information about the projects and after discussions with SCS Engineers staff who have been involved in such projects.

LFG UTILIZATION PROJECTS IN THE NORTHEAST

The survey identified 39 projects operating in the 11 states comprising the Northeast region with 26 other projects in various stages of development. A listing of the operating projects and the projects under development is presented in Exhibit 3-1.

LFG INDUSTRY INTERVIEWS

In order to obtain representative comments regarding the state of the LFG recovery industry today, both large and small LFG developers were interviewed, as well as utilities and financial institutions. The utilities are the end-users of the energy being produced, and the financial institutions with whom we spoke currently are financing LFG recovery projects.

LFG Developers

An estimated 40 LFG developers are active in the U.S. Thirteen of these developers were contacted. We concentrated on the developers with multiple successful projects and interviewed firms that are major nationwide LFG developers, as well as active developers in the Northeast.

In addition, we contacted several small developers who are likely to develop the small sites that are typical in the New England states. Such sites can attract the small developer because they have lower capital investment requirements and offer an opportunity to gain valuable project experience.

Landfill Owners

Several landfill owners and operators active in LFG recovery were interviewed. Even though the project developer is the expert on such projects, the owner/operator can

EXHIBIT 3-1. LFG RECOVERY PROJECTS IN THE NORTHEAST

State	Number of Existing Projects	Projects Under Development		
		Number	Landfill/Location	LFG Developer
Connecticut	1	1	Shelton	
Delaware	0	1	Cherry Island	Hazox Energy
Maine	0	0		
Massachusetts	1	9	Barre East Bridgeport Fall River Halifax Lowell Plainville Randolph Springfield Worcester	Phillips Energy BFI BFI BFI Williams Energy Laidlaw Gas Recovery System BFI Phillips Energy Williams Energy
Maryland	3	2	Bowley's Lane (Baltimore) Woodland Quarry (Baltimore)	Curtis Engines Curtis Engines
New Hampshire	2	2	Nashua Stowe	Suncook Energy Corp. Vermont Energy Recovery
New Jersey	5	5	Edgeboro (Middlesex County) Edison (Middlesex County) ILR (Middlesex County) HMDC Balefill HMDC Kingsland Landfill	O'Brien Environmental Energy O'Brien Environmental Energy O'Brien Environmental Energy O'Brien Environmental Energy O'Brien Environmental Energy
New York	16	2	Mohawk Valley (Frankfort) Seneca Falls	Waste Management Funnell Industries
Pennsylvania	8	3	Harrisburg Lycoming County Scranton (Keystone)	Organic Waste Technologies Lycoming County Organic Waste Technologies
Rhode Island	1	1	Central Landfill (Waste Heat)	Genesis Energy Systems
Vermont	2	0		
TOTAL	39	26		

provide additional insights. Most owners interviewed were either municipal authorities or private owners with multiple sites who had LFG recovery projects operating on their landfill. Several had new projects in the planning stages.

Energy Users

Electric and natural gas utilities using energy produced from LFG projects were interviewed. Individuals in this group reported their experiences from these projects and provided opinions about this energy source.

Financial Institutions

Several financial institutions active in financing LFG recovery projects were contacted. Their concerns and requirements are different from the developers, owners, or operators. The financial institutions were questioned about lending requirements and their perceptions about the LFG recovery industry. Their suggestions were requested about improving the likelihood of project funding.

Interview Approach

The general approach used in the interview process started with the accumulation of available information about each LFG recovery project, based on published reports, in-house files, etc. Information was gathered about projects, companies, and individuals and their experience in the LFG industry (number of projects, locations, sizes, etc). Telephone interviews were then conducted to verify the file data and to complete it. In addition, information about successful project characteristics, project barriers, and recommendations to overcome these barriers were discussed and recorded. Topics of particular interest included the following:

- Landfill and LFG recovery/utilization systems;
- Economics — energy contract revenues/terms and tax incentives;
- Institutional issues; and
- Environmental permitting and regulatory issues.

Exhibit 3-2 lists the industry contacts. Generally these contacts provided valuable information for this project.

EXHIBIT 3-2. LFG INDUSTRY CONTACT LISTING

	LFG Developers	Location
1	Air Products, Inc.	Allentown, PA
2	Bio Development Corp.	Bedford, NH
3	BFI Gas Recovery Systems	Houston, TX
4	Cambrian Energy Systems	Santa Monica, CA
5	Energy Tactics, Inc.	Yaphank, NY
6	Hayden-Wegman, Inc.	Boston, MA
7	Laidlaw Gas Resource Systems	Newark, CA
8	Michigan Cogeneration Systems	Novi, MI and San Diego, CA

EXHIBIT 3-2. (Continued)

	LFG Developers	Location
9	O'Brien Energy Systems	Philadelphia, PA
10	Palmer Capital	Cambridge, MA
11	Phillips Energy	Waitsfield, VT
12	Vermont Energy Recovery	Brattleboro, VT
13	Waste Management of North America	Oak Brook, IL

	Landfill Owners	Location
1	Los Angeles County Sanitation Districts	Whittier, CA
2	New York City Department of Sanitation	New York, NY
3	Connecticut Resource Recovery Authority	Hartford, CN
4	Delaware Solid Waste Authority	Dover, DE
5	Fairfax County, Virginia	Fairfax, VA

	LFG Energy Users	Location
1	Brooklyn Union Gas	New York, NY
2	Burlington Electric Department	Burlington, VT
3	Long Island Lighting Company	New York, NY
4	New England Power	Westborough, MA
5	Public Service Electric & Gas	Newark, NJ

	Financial Institutions	Location
1	State Street Bank	Boston, MA
2	First Union Bank	Atlanta, GA
3	Zahren Financial	Avon, CN

EXHIBIT 3-2. (Continued)

SECTION 4

SUCCESSFUL PROJECT CRITERIA AND IMPEDIMENTS TO LFG UTILIZATION

INTRODUCTION

Based on SCS' experience and the survey, we have identified (1) what makes a LFG project successful; (2) impediments to a successful project; and (3) recommendations on how these barriers can be surmounted. This information is presented in the following subsections:

- **Landfill Characteristics** — e.g., landfill size, types of refuse received, active versus closed sites.
- **LFG Collection Systems** — i.e., types of wells, LFG yield estimates, wellfield operation and maintenance.
- **LFG Utilization Systems** — project size and technologies.
- **Economics** — revenue ranges for the different utilization methods, financing alternatives, and methods to take advantage of federal tax credits.
- **Institutional Factors** — utility contracts and landfill owner/developer relationships.
- **Regulatory Issues** — including air emissions, condensate management, and permitting.

LANDFILL CHARACTERISTICS

Several factors are hallmarks of success when defining which landfills are good candidates for LFG recovery systems. In addition, characteristics common to unsuccessful projects are described. In discussions with both large and small LFG developers, general consensus was reached on certain parameters outlined below.

Successful Factors

Landfill with 2 Million Tons of Refuse in Place--

LFG recovery systems are most successful on larger landfills which accept municipal solid waste (MSW). LFG developers prefer a landfill with at least 2 million tons in place. Such a landfill typically generates enough LFG to support a utilization project for the 10-year or longer period that developers desire. A landfill of this size requires a community of approximately 200,000 people disposing of refuse over a 10-year period.

Several of the larger developers only pursue projects at landfill sites with at least several million tons in-place. However, smaller developers may pursue projects at landfills with 3/4-million tons in-place, where economics are justified.

Landfill Area of 30 Acres or More--

EXHIBIT 3-2. (Continued)

Landfills should have 30 acres or more of refuse in-place. Significant acreage should be at or near final grade to provide a location for the installation of the LFG collection system.

Refuse Depth of 40 Feet or Greater--

Landfills with depths of 40 feet or more are suitable candidates for LFG recovery, but deeper landfills are preferred. It can be inefficient to extract LFG from areas with less than 40 feet in depth due to atmospheric influence and the need for additional wells.

Active Filling for at Least 5 Years--

Organic material generates LFG after being landfilled and covered. Most landfills require 5 to 10 years of active filling to have sufficient refuse quantities in place to provide sufficient recoverable LFG. Good filling/waste receipt records and topographic maps are valuable tools to confirm the amount of refuse in place, including the period of time over which refuse was received.

Landfills Accepting Refuse for Several Additional Years--

All interviewees agreed that an active landfill with at least several more years of operation is the best candidate from which to recover LFG. Landfills with remaining life will receive additional quantities of refuse, thereby extending the period of time over which LFG is generated. Closed sites will generate LFG for fewer years. Several of the developers will not pursue projects at closed sites.

<u>Impediments</u>

Landfills Too Small to Support a Utilization Project--

As stated above, not all landfill sites are candidates for LFG utilization projects. The lack of required LFG quantities and/or poor LFG quality is the major impediment. These conditions can occur if the landfill is too small or too old. The landfill size requirements identified above are most applicable for electrical generation projects. Furthermore, the economics of developing smaller landfills (less than 1 million tons in place) is improved if a direct energy user is located near the site.

Landfills Which Receive Large Quantities of Non-Municipal Solid Waste (MSW) or Liquids--

Landfills which receive a large percentage of non-organic wastes (i.e., industrial, construction and demolition debris, inert material, etc.) generally are not good candidate sites. Non-organic material does not decompose and produce methane. Landfills which receive significant quantities of liquids or sludges may be high generators of LFG due to the high moisture content, but the LFG may be more difficult to extract, and/or the duration of LFG generation may be shortened.

EXHIBIT 3-2. (Continued)

Landfills Which Have Been Closed for Several Years--

The economics of a successful project are closely tied to the LFG supply rate. LFG production is on the decline at landfills which have been closed for several years. Sites which will receive refuse for additional years provide new areas where the LFG collection system can be installed to maintain production as other areas decline in production.

Landfills with Shallow Refuse Depths--

Vertical collection wells are most often used to extract LFG. Efficiently extracting LFG by using vertical wells is difficult if a landfill has shallow refuse depths (less than 40 feet). The volume of well influence is directly related to the well depth; shallow wells draw LFG from a significantly smaller volume than deep wells. A higher well density increases drilling costs and operation and maintenance (O&M) costs. Extracting LFG from shallow wells without introducing air into the system also is more difficult.

Limited Available Information on the Landfill History--

For many sites, limited background information is available regarding the landfill's history; i.e., how the landfill was constructed, when refuse was received, and how much is in place. Often sites started as uncontrolled fills without filling records. Recordkeeping practices improved in the 1980s and currently are fairly reliable.

During the initial project planning period, prospective developers should review available landfill records, talk with the landfill operation staff, and review engineering drawings/reports, if any exist. A better understanding of the landfill's history can provide data that may support a decision whether to develop the site.

Limited Number of Candidate Landfills in the Northeast--

Opportunities for private developers may be limited in the Northeast since many landfills are closing, and the new larger landfills are controlled by the major waste firms (WMI and BFI) who may self-develop projects. Many LFG developers will have to concentrate on smaller sites owned and operated by municipalities and/or small landfill owners.

LFG COLLECTION SYSTEMS

<u>Successful Factors</u>

Use of Vertical Wells and/or Horizontal Trenches--

Vertical wells are most often used for LFG extraction. A recent industry trend is the use of vertical wells and horizontal trenches in combination. Vertical wells can be installed on the closed section(s) of the landfill which are at final grade, while horizontal trenches can be installed in the active filling areas. The installation of horizontal trenches allows for collection of LFG in areas where it otherwise might not be recovered. Wells and headers should be kept accessible to facilitate operation and maintenance.

EXHIBIT 3-2. (Continued)

LFG Recovery Yield Estimates--

Developers should take a conservative approach to estimating LFG recovery yields. LFG production varies from site to site, making projections difficult. Several methods can be used to estimate the quantity of LFG that can be collected and utilized:

- Model theoretical LFG production using computer models;
- Conduct an active or passive LFG flow test program; and/or
- Measure flows, etc., from an existing LFG collection system.

Field test programs can provide necessary site specific information about the landfill.
Passive test programs (no active extraction of LFG) are often used to characterize refuse tailings, measure subsurface pressures, gas concentrations, and measure liquid levels in the landfill.

During an active program, several extraction wells are installed and connected to a portable blower and pumped for a period of time (ranging from several days to weeks). The intent is to extract LFG at the landfill's generation rate by monitoring well influence with test probes. Both types of field programs can provide useful data on LFG generation rates and criteria for LFG collection system design and operation.

Existing LFG Collection System--

Actual LFG production rates can be measured from existing collection systems, removing much of the risk for a developer entering a new project. The utilization equipment can be more accurately sized for the available LFG flow. Several major waste management firms have internal company policies to install control systems as part of their landfilling operations. The cost of these systems often is attributed to the landfill operational cost rather than the recovery system cost, thereby improving the viability of subsequently- installed utilization equipment.

Liberal Use of Condensate Traps--

Well-designed LFG collection systems require sloped piping (to allow drainage of condensate) and numerous condensate drop-out points. Low points can develop from differential settlement and lack of adequate slope in the piping network. Traps can limit header blockages at low points which could restrict LFG flow.

Regular Operations and Maintenance of Wellfield--

A routine wellfield O&M program is required. The wells require periodic balancing and adjustments to maintain high methane quality gas (50 percent or more). Routine O&M helps to keep LFG production at desired levels, identifies problem areas, and provides needed data to analyze LFG production rates.

EXHIBIT 3-2. (Continued)

<u>Impediments</u>

Unachievable LFG Production Estimates--

The lack of sufficient quantities of LFG is the most common impediment to successful projects. Oversizing of projects (i.e., installing gensets or other equipment that have more capacity than the potential wellfield yield) has led to poor economic performance at some sites and several project shutdowns. Measures which can limit the risk of LFG production shortfalls include:

- Making realistic estimates of LFG yield that are based on the landfill characteristics, conservative unit rates of LFG generation, and a model incorporating conservative values. Avoid overly optimistic estimates based on project financial goals.

- New LFG developers should consider entering a partnering relationship with an experienced LFG developer.

- Retain a consulting engineer with proven experience in LFG recovery to provide technical support. The support may include field testing, engineering design, and other assistance in implementation.

- Commission third party reviews by an experienced engineer.

- Prove the LFG yield by measuring flow rates on existing LFG collection systems (or installing partial collection systems) prior to committing to purchase utilization equipment.

LFG generation rates are often quite variable. Seasonal variations as well as climate changes can vary production 20 percent or more. Over time LFG generation rates decrease as the decomposition fraction of waste mass decreases. LFG recovery facilities must strike a balance between being sized for the volume of LFG currently being generated and the volume of LFG that will be generated in 5 or 10 years. Inadequate design, operation, and maintenance of wellfields can contribute to insufficient LFG yield.

Elevated Liquid Levels--

High liquid levels in a landfill can reduce the effectiveness of extracting LFG from vertical wells. These high liquid levels can cover the well casing perforations and effectively block the withdrawal of the LFG. It is a long, slow, and expensive process to lower liquid levels within the landfill. Limited success has been achieved using combination LFG/leachate wells or horizontal trenches for recovery in landfills with high liquid levels.

Differential Settlement of the Landfill Surface--

Landfills are subject to differential settlement while being filled and during the closure period. Settlement can cause damage to extraction wells and cause low points to develop in the header system which can restrict LFG flow. Header systems should be sloped to accommodate settlement without creating condensate blockages.

Poor Final Cover Systems--

EXHIBIT 3-2. (Continued)

A variety of landfill covers exist, ranging from an intermediate (temporary) soil cover (e.g., 12 inches of permeable soil) to a final cover system in compliance with the recent Subtitle D regulation (such cover systems include a low permeability soil or synthetic membrane barriers). In any case, surface cracks and eroded areas should be repaired to limit air intrusion into the landfill. Currently, many landfills are being capped with a geomembrane as part of the final cover system. How a geomembrane will affect LFG generation and collection is not yet completely known. The membrane may slow down the LFG generation rate (by limiting moisture), increase the duration of LFG generation, and increase the LFG collection system efficiency (higher vacuums could be applied with less air intrusion).

Wellfield Damaged by Landfill Operations--

Wellfield components that are installed in active filling areas can be damaged by landfill equipment (compactors, bulldozers, refuse trucks, etc.); major damage can result in complete plant shutdown. If LFG collection systems are installed in active filling areas, wellheads should be protected and well marked. Good relationships with and education of the landfill operations personnel are needed to limit this problem.

LFG UTILIZATION SYSTEMS

The technology of using LFG for energy applications is relatively well developed. Over 125 projects are in operation; some projects report more than 90 percent plant on-line performance. As a result, many of the technical parameters with these projects are well established.

<u>Successful Factors</u>

Use of Proven Technology/Equipment--

In order to reduce risk, developers — especially new developers — should utilize proven technology; i.e., avoid new processes or untried equipment. The majority of successful projects use conventional proven equipment. The proceedings, published by the Solid Waste Association of North America (SWANA), of its Annual LFG Symposium routinely discuss system configurations, operating criteria, performance data, and problems/remedies. Several vendors now manufacture equipment specifically designed for LFG applications.

Medium Btu Use of LFG--

Using LFG to replace boiler fuel is the preferred option for LFG utilization. This alternative has the lowest capital cost and can displace higher cost natural gas or fuel oil. Ideally, the end-user will be located nearby — less than 2 miles is desirable. Of more importance than location is the criteria that the LFG customer have a continuous, large demand, preferably a 24-hours, 7-days-per-week, year-round operation.

EXHIBIT 3-2. (Continued)

Minimum Electrical Generation Project Size--

According to several developers, projects should be at least 1.6 to 2 MW of electrical power output. This size corresponds to a two engine system using engine generators from Caterpillar (1.6 MW) or Waukasha (2.0 MW). A plant of this size would require approximately 650 to 800 cfm of LFG to run at full capacity.

The selection of internal combustion (IC) engines or gas turbines for generating power is dependent upon the project size, emission requirements, developer experience and preference, and equipment prices. The industry trend is towards larger IC engines (800 to 1,000 kw units each), with multiple units installed to meet the plant's generating capacity or gas turbines (3,000 kw). Both IC engines and gas turbines have proven performance with no reported clear technical advantage to either system.

Upgrade to High Btu Gas--

Several technologies currently are used for upgrading LFG to pipeline-quality gas. Processes used include the Selexol™ system which is used in the Fresh Kills (New York) and Colorado Springs (Colorado) projects. Pressure swing absorption technology is used in Cincinnati, Ohio; and the Kryosol™ process is used in a Birmingham, Alabama project. According to one vendor, the pressure swing absorption technology is cleaner and has higher recovery rates at comparable cost than the Selexol™ system.

Use of Standardized Plant Designs--

Several of the major developers utilize "standard plant" designs and equipment, thereby offsetting repetitive architectural and engineering costs associated with custom plants. Utilizing standard-model equipment has allowed operating experiences to be shared, thus minimizing learning curve duplication and permitting warehousing for major spare parts (i.e., engines, generators, compressors or blowers). Having spare equipment readily available can save thousands of dollars in lost revenue each year.

O&M Personnel Service Several Facilities--

Developers with multiple facilities use the same maintenance personnel to service several projects. Remote sensors and alarms are used to notify operators of problems that need attention at unmanned facilities. Personnel are pooled to perform major equipment maintenance activities such as engine overhauls.

Waste Management of North America (WMNA), which owns and operates over 25 projects, conducts training sessions for plant operators from around the country to discuss system operations and new developments.

<u>Impediments</u>

The Optimum Amount of Pre-Processing of LFG--

The level of gas cleanup necessary for LFG utilization has not been established by the industry. Various LFG developers/operators have different opinions regarding the amount of pre-processing versus equipment maintenance. These tradeoffs are dependent upon the utilization technology and the developer's experience. At a minimum, filtration and some moisture removal are needed

EXHIBIT 3-2. (Continued)

upstream of the blower or compressor. At the other end of the spectrum, several vendors remove LFG condensate by cooling the LFG with a refrigeration or air cooler system to eliminate additional volumes of condensate. The LFG is sometimes reheated with additional filtration points prior to combustion in the engines or other use.

In summary, knowledge regarding the appropriate level of gas cleanup for the various utilization technologies is limited to technically-inclined and experienced developers. Accordingly, less-experienced LFG developers may have a tendency towards inadequate pre-processing cleanup, which can cause additional equipment down time, replacement, or repairs.

Unrealistic O&M Budgets--

Some LFG developers historically have underestimated the capital and O&M costs of utilization projects. Many of the projects appear to be operated "near the edge," economically. Several developers use a maintenance team to service several projects and use remote sensors/alarms to avoid dedicating O&M personnel full-time to individual sites.

At many projects, the LFG collection systems do not receive enough attention. O&M sometimes focuses on the power plant with limited attention to the wellfield unless it shuts the plant down or the utilization system's efficiency decreases dramatically. O&M of the wellfield (wellfield balancing, replacing wells, condensate trap repairs, collection piping adjustments to eliminate low points, etc.) is required to provide a reliable fuel supply to the utilization system.

Lack Of Medium Btu Markets--

The primary hurdle to direct sale of LFG is finding a large, continuous LFG user within a reasonable distance of the landfill. If the customer is an intermittent user or cannot use all of the recovered LFG, then the excess LFG may have to be collected and flared. Good potential users include heavy industry, automobile and chemical plants, refuse burning power plants and incinerators. The developer must evaluate the reliability of such customers as long-term LFG purchasers (10+ years).

Development of Alternative Technologies to Utilize LFG--

Several alternative utilization technologies for LFG and other biomass are under development. Technologies include: use of LFG as a vehicle fuel, waste heat systems (including the Organic Rankine Cycle), and others. Additional support from Federal agencies (primarily DOE and EPA) and other organizations (Electric Power Research Institute, Gas Research Institute, etc.) to develop these technologies would aid in encouraging such uses.

Alternative technologies or additional equipment is needed in areas with strict air emissions control requirements (non-attainment areas). If the new technologies are able to achieve higher thermal efficiencies and lower emissions, LFG developers may have alternatives to existing systems. This may increase the capacity of existing projects and allow the development of new projects.

ECONOMICS

<u>Successful Factors</u>

Adequate Project Revenues--

EXHIBIT 3-2. (Continued)

Project revenues should be sufficient to cover all O&M costs, debt service, royalty payments to the landfill owner, as well as to provide an acceptable rate of return to the developers/investors for privately-owned projects. The required revenues for the energy produced from LFG projects vary, depending upon LFG use. Minimum (rule-of-thumb) acceptable purchase prices reported by LFG developers in 1993 are:

Electrical Generation -- 4.75¢ to 6.5¢/kWh. These projects must be part of the utility's baseload facilities, not just peak-load generators.

Medium Btu -- $2.00 to $3.00/million Btus.

Pipeline Quality Gas -- $3.50 to $4.00/million Btus.

Access to Internal Financing--

LFG projects developed by large waste management firms usually are self-financed at below-market rates. This access to capital improves their ability to competitively respond to proposals (both landfill owner and utility RFPs) and execute projects. One major developer (WMNA) reportedly will pursue projects while receiving as little as 2.3¢ per kWh. This is primarily due to having low financing costs, using standardized facility designs, receipt and use of Tax Credits, and treating the cost of the collection system as a landfill cost rather than as an LFG recovery system cost.

Internal Rate of Return of 15 to 20 Percent Required--

Project developers/investors expect a minimum 15 to 20 percent internal rate of return (IRR) on LFG utilization projects. These returns are warranted because of the relatively high level of risk associated with these projects.

Ability to Utilize Section 29 Production Tax Credits--

Projects should be structured to take advantage of the Federal Section 29 Production Tax Credits for producing fuel from nonconventional sources. Several of the larger developers have established partnership arrangements with equipment financing subsidiaries to invest in these projects.

One scenario used to structure a project is:

- A LFG developer establishes "Gasco" and "Genco" companies.
- The landfill owner leases the LFG rights to the Gasco for a set royalty.
- Gasco constructs and operates the LFG collection system and sells the recovered LFG to Genco.
- Gasco is eligible to receive Section 29 tax credits based on this sale of LFG.
- Genco builds and operates the power plant, selling the energy to the local utility and receiving the revenues.
- The Gasco and Genco companies often are partnerships or joint ventures between LFG developers and/or investors. The Gasco owners or investors need to have an appetite for Tax Credits or be able to sell the Tax Credits to other investors.

EXHIBIT 3-2. (Continued)

Impediments

Utility's Low Avoided Cost, Slow Demand Growth, and Increased Competition Among Fuel Sources--

Many of the utilities in the Northeast and throughout the country are experiencing low utility avoided costs and a decreased demand for electric power. The energy contract prices identified previously are difficult to obtain in the current energy market. LFG projects often must compete with other non-utility generators for power contracts and with other renewable technologies in specialized procurement.

Inadequate revenues for energy produced from these projects is the major impediment to LFG utilization. Other impediments (both technical and non-technical) can be overcome at a cost, if the revenue stream is sufficient. Activities which utilities could use to justify higher revenues include:

- Levelized wholesale rates for power sales. Utilities could "front load" energy contracts to allow the LFG developer to retire debt service costs early in the project.

- Issuance of "green RFPs," capacity set asides, and regulatory incentives or mandates for the development of renewable energy sources.

A study conducted for EPA identified several recommendations to overcome economic barriers [USEPA, 1993]. These recommendations included:

- Increasing the value of federal tax credits and furthering state regulations benefitting LFG energy users.

- Imposing a "methane tax" on decomposable waste that is landfilled.

- Supporting LFG energy uses with a levy on fossil fuel use (reflecting the emission consequences of fossil fuel use) similar to the British non-fossil-fuel-obligation (NFFO). The NFFO, instituted in 1989, requires utilities to buy a certain amount of electricity from non-fossil fuel sources, including nuclear power and certain renewable energy technologies, one of which is LFG. The NFFO is not a permanent subsidy for renewable energy technologies, but a market-enabling mechanism to allow industries to develop to commercial viability.

Perception of High Risk by Financial Institutions--

Financial institutions consider LFG projects to be relatively high risk. Generally, financial institutions are unfamiliar with the concept and use of LFG. Most "alternative" energy production technologies tend to be viewed as unproven or risky. As a result, such projects must earn high returns in order to attract financing.

The banking community would like to see LFG projects added to the U.S. Comptroller of the Currency's list of approved investments for national banks. This action would encourage banks to invest in these projects in a manner similar to low-income housing projects. Internal bank and bank regulatory agency approvals would be facilitated by this procedure.

Access to Capital: Investor Financing--

EXHIBIT 3-2. (Continued)

Access to capital is a problem for many smaller developers. Traditional financial lenders avoid LFG projects because of the relatively low capital requirements ($1 to $5 million) and the high risk; such lenders also are unfamiliar with LFG technology.

In order to obtain project financing, a 50/50 equity/vendor partnership often is required. Having a market for the Section 29 Production Tax Credits can help in obtaining equity financing. Each project should be structured to have a transaction which can be financed. One lender's recommendations to developers for raising outside capital were:

- Major contracts (gas lease, power sales, operating agreement) should extend beyond the life of the loan.
- The contracting parties should be financially sound.
- Construction contracts should be fixed price, turn key, with liquidated damages.
- The contract terms should pass through the project (price escalators, *force majeure* provisions, indemnifications).
- A proven technology with a successful track record should be planned.
- The developer should have identified all required permits and have arranged for insurance to cover all phases of the operation.

Inability to Use Tax Credits--

The Section 29 Production Tax Credits cannot be used directly by many developers because the credits must be applied against taxable income above the Alternate Minimum Tax (ATM). Tax Credits can be transferred to a third party, but must be discounted to be sold. Tax Credits may be discounted from 25 to 75 cents on the dollar.

Several LFG developers have established partnership arrangements with equipment vendors. Some investment offerings currently are in the planning stage where tax credits from multiple projects would be acquired and sold to investors who could utilize them. This development would provide a needed outlet for the Tax Credits which would help finance the project.

Inadequate Capitalization--

Some LFG developers are undercapitalized and lack experience on LFG projects. These developers may have limited financial resources and have insufficient reserves to cover schedule delays and/or unexpected events. Realistic project *pro formas* should be prepared.

Funding for the Renewable Energy Production Incentive (REPI) Program--

The LFG industry is hopeful that Congress will fund this new program. The 1.5 cents/kWh payments would encourage public/private partnerships in new projects and significantly improve LFG project economics. LFG projects would further benefit if a project could receive both the Section 29 Production Tax Credits (for the production of fuel from biomass) and the REPI funds (for the generation of electric power from renewables). Funding of this program could have a positive impact on the industry, especially if the funding was guaranteed for a 10-year period.

EXHIBIT 3-2. (Continued)

INSTITUTIONAL ISSUES

Successful Factors

LFG Developers with a Proven Track Record--

Landfill owners should select experienced developers who have successfully **completed** one or more of these projects. Because projects can take several years to implement, experienced firms should understand the details of LFG recovery projects and the financial resources required to complete the project.

Pro-Active Utility Companies: "Green RFPs"--

The LFG industry should continue to pursue and support legislative efforts to establish renewable energy set-asides or "Green RFPs." Because LFG utilization technologies are fairly well established, LFG projects should be well positioned to compete against other renewables in these types of solicitations.

Renewable technologies have the potential for an important role in a utility company's efforts to lessen air emissions and oil dependence. One utility company's stated objectives for the purchase of power from renewables, as indicated in its RFP, were to: [New England Power, 1991]

- Assess the commercial readiness and potential of renewables in New England.
- Gain experience with renewable resource project licensing, operating characteristics, and costs.

EXHIBIT 3-2. (Continued)

- Promote public acceptance and understanding of renewables technologies.
- Stimulate further renewable resource development.

Impediments

Equitable Risk/Reward Sharing Between the Landfill Owner and LFG Developer--

The procurement documents issued by municipalities for LFG recovery projects often do not distribute risks equitably. The party exposed to the most risk in the project should receive the highest return. Some landfill owners try to shift LFG migration and explosion risks to the developer.

LFG migration and control should remain the responsibility of the landfill owner. The developer's principal objective is to maximize the utilization of LFG, not control migration or emissions. Developers are reluctant to pursue projects where potential liabilities for LFG control must be accepted. To limit this liability, the landfill owner can maintain the responsibility or issue a separate contract for LFG control to the developer or a third party.

The landfill owner would then maintain complete control of all operations on the landfill, which includes LFG odor and migration control. Although this action would limit the developer's control of the fuel supply, associated costs and risks also are reduced. The landfill owner is more likely to understand the local LFG issues and obligations and have realistic financial (royalty) and operational expectations.

Landfill Owners' Perception that LFG Developers Earn High Profit--

Some landfill owners have unrealistic expectations from potential LFG utilization projects, believing that the landfill may be a "gold mine" for the LFG developer. Owners need to recognize the costs and potential profits of these projects. Several unrealistic expectations have included:

- High royalties - up to 25 or 30 percent.
- Performance guarantees.
- Passing responsibility for LFG monitoring, odors, surface emissions, and migration control to the developer.
- Most or all risks assumed by the developer.

Developers need to form a good relationship with the landfill owner with open lines of communication.

Inequities (Excessive Expectations/Contract Terms) in "Competitive Bid Process"--

The competitive process by which projects are procured has shortcomings. Many landfill owners are selecting developers based on promised royalties, not qualifications or experience. Inexperienced developers have offered high royalties to secure projects, only to fail later when insufficient returns are generated. Other project's LFG development rights are restricted by developers who never get the projects on-line. These scenarios often result in difficult relations between the developer and the landfill owner and unmet financial performance. The owners would be well served to base contractor selection on qualifications, experience, project approach, and

EXHIBIT 3-2. (Continued)

financial conditions. Preparing a short list of potential developers based on a pre-qualification process can be helpful.

Royalty System--

Several shortcomings exist in the royalty system where developers give the landfill owner a percentage of the gross energy sales. The developer must extract the LFG from the landfill, process it, generate power (or other forms of energy), and sell the energy to the end-user. The owner receives royalties based on these sales, not based on the value of the "raw LFG." Potential remedies (suggested by LFG developers) include:

- LFG royalty payments should go to a landfill operational fund - not just to the municipality. This process might improve the level of cooperation between landfill personnel and the developer.

- Developers should be allowed to achieve a minimum rate of return (to cover investment costs) on the project prior to the payment of royalties.

Utility Companies' Low Interest in LFG Recovery Projects--

LFG recovery projects often have received little real support from utility companies. Developers perceive that utility companies view LFG projects as being too small and time consuming, and that utility companies prefer to generate their own power rather than buying from independent power producers.

Since LFG projects are small,demand-side projects, the electricity is generated near the ultimate users; thus, the distribution costs are low. Higher energy prices paid to these projects can be partially offset by lower distribution losses and costs. To increase interest in these projects, utility companies would like the regulatory agencies (Public Utility Commissions) to allow financial incentives for the purchase of renewable power. Incentives could include:

- Receiving tax credits (currently tax credits are available to municipal owners and developers).

- Allowing utility companies a return on these investments.

- Allowing utility companies to pass on rate increases to customers.

- Allowing environmental credits that can be used or traded to offset other discharges.

Utility Contract Terms--

Developers' experiences with utility companies range from cooperative to difficult. Developers desire standard energy purchase contracts with clear contract terms and interconnect requirements. Utility RFPs should be designed to eliminate excessive transaction costs. Sometimes, a fully-engineered project is required to respond to an RFP.

Projects following the standard schedules (already approved) should be allowed by the state utility commissions with no subsequent review required. Such a process could save 6 to 12 months in the approval/negotiation period.

EXHIBIT 3-2. (Continued)

Several problems with the current solicitation process used by utility companies are:

- Preparation of bid responses is expensive; since the projects generally are small, the risk is high compared to the reward.
- Bids are difficult to price because LFG developers' responses must be competitive with other independent power producers.
- LFG developers often have difficulties entering into pre-bid agreements with landfill owners. Publicly-owned landfills usually must go through a formal RFP process, which precludes firm fuel supply commitments being included in the responses.

Measures that reduce the impact of these problems can expedite project development.

Inexperience of Some LFG Developers--

Many problems of the less-than-successful projects can be attributed to developer inexperience. LFG developers should stay abreast of current and new developments in the field. New developers should draw on the experience gained by others over the past 20 years. Several new developers have entered into partnership relationships with others to gain this experience.

SWANA sponsors an LFG Symposium in March each year. This forum exchanges good, useful information. The published proceedings include technical and economic information, and regulatory updates on LFG control and recovery projects.

ENVIRONMENTAL REGULATORY ISSUES

<u>Successful Factors</u>

Use of Lean Burn Internal Combustion Engines or Gas Turbines--

LFG electrical generation projects have successfully used both IC engines and gas turbines for power generation. Lean burn IC engines or gas turbines have been used in non-attainment areas where emission limits are of concern. Because of the lower combustion temperatures involved, NOx emissions are considerably lower for gas turbines than for IC engines.

Project Meetings with State Regulators (Solid Waste and Air)--

Meetings with the state regulatory agencies during the project development stage help to limit future problems. Developers need to understand the regulations, communicate with regulators (educate them about LFG), and develop a cooperative relationship. Issues concerning air emissions, condensate management, landfill closure modifications, etc., should be discussed; and regulatory concerns identified and resolved.

Several developers have even applied for and obtained air permits prior to being selected by the landfill owner to develop the project. This action significantly improves their chances for selection to develop a site and shortens the project development period.

Implementation of Proposed New Source Performance Standards (NSPS) for Landfills--

EXHIBIT 3-2. (Continued)

The proposed NSPS for landfills should have a positive impact on LFG utilization. The NSPS regulations may result in the installation of LFG collection systems at many landfills, and these systems could support energy projects. The LFG collection and control systems could be considered a landfill-related cost, and not a cost of the utilization project, thereby improving the economics of the project. Also, LFG production (quantities and quality) could be monitored to "prove the reserves," prior to implementing a utilization project.

LFG Condensate Managed with Landfill Leachate--

LFG condensate typically can be combined with the landfill leachate and managed similarly. Many projects dispose the condensate with the leachate to a publicly operated treatment works (POTW). If the landfill is lined and has a leachate collection system, Subtitle D regulations permit condensate to be returned to the landfill.

<u>Impediments</u>

Air Emissions in Non-Attainment Areas--

In many areas of the Northeast, difficulties exist in siting new combustion sources in non-attainment areas due to NO_x emissions. Currently, project size may be limited to 2 MW in severe non-attainment areas without offsets or other control measures.

Developer recommendations to overcome these difficulties include:

- Regulatory agencies should compare air emissions from a non-controlled landfill to the proposed utilization project (i.e., compare no action scenario to the project emission values).
- EPA could give a general Prevention of Significant Deterioration (PSD) to LFG recovery projects using pre-approved technology.
- Development of new emission control technologies is needed; e.g., new pollution control equipment, lower-emission engines, and alternatives to IC engines or gas turbines for generation of electric power.

A study conducted for the U.S. EPA identified several recommendations to overcome non-technical barriers included: [USEPA, 1993]

EXHIBIT 3-2. (Continued)

- Allowing greenhouse gas and NMOC emission "offsets" for LFG energy use.

- Using environmental "balance sheets" for LFG energy conversion that consider the total picture, not only the secondary emissions that tend to be the current focus of regulations.

Flare/Landfill Offset Credits--

Projects which recover and utilize LFG are subject to more stringent regulations than sites where flaring of LFG occurs. Instead, incentives should be provided to utilize the LFG versus its flaring or having no system in place. Developer recommendations included:

- Provide offset credits for the flare emissions (or surface emissions from a landfill without a system) to be considered when permitting the utilization equipment.

- Provide offset credits for the environmental benefits from the reduced methane and CO_2 emissions from LFG recovery projects. Several states (Massachusetts and New York) are establishing programs where such benefits (environmental externalities) are given monetary value. A study to assess the impact of these programs along with alternative LFG utilization technologies is being sponsored by the Northeast Regional Biomass Program.

Compliance with Various Permitting Agencies--

LFG projects require permits from several state regulatory agencies. Responsibilities and requirements often are not well defined between the air quality and solid waste divisions. Projects are subject to bureaucratic red tape and unnecessary delays. In each state, one agency (Air Quality or Solid Waste) should be designated as the lead permitting agency and be responsible for coordination with the other divisions.

The state Energy Offices could lend their support in coordination between the regulatory (solid waste and air) agencies, utilities, and Pubic Utility Commissions during project implementation.

State or Federal Superfund Sites--

Several developers have pursued projects at landfills which are state or Federal Superfund sites. These sites continue to be difficult to develop due to the reluctance of both developers and investors to pursue the project. Conducting a project at a Superfund site increases potential liability and cost. Several developers have pursued promising projects until they were overwhelmed with the amount of documentation required (submittals, correspondence, and endless meetings) and excessively stringent levels of health and safety required (e.g., Level B personnel protection may be required for O&M activities).

Utilization of LFG should be encouraged by the regulators at sites which have had or need to have LFG control systems installed as part of the site remediation. However, a subsidy may be necessary to encourage such development.

Liability concerns have increased the difficulty in obtaining financing for LFG projects. Lenders/investors are concerned about potential clean-up costs under the Comprehensive Environmental Regulatory Clean-up Liability Act (CERCLA). The project financing needs to be structured in a way that insulates the lender from potential CERCLA liability.

EXHIBIT 3-2. (Continued)

Disposal of LFG Condensate--

Disposal of LFG condensate can be an impediment. As discussed in Section 2, condensate collection can be costly if the cognizant regulatory agency does not allow the condensate to remain in the landfill; i.e., requires that it be collected. Under certain conditions, condensate when stored, has separated and failed the ignition test that caused its classification as a hazardous waste. However, condensate generally has characteristics similar to landfill leachate and often can be treated similarly.

EXHIBIT 3-2. (Continued)

SECTION 5

IDENTIFICATION OF CANDIDATE NORTHEAST LANDFILLS FOR LFG UTILIZATION

To assess the LFG utilization potential in the Northeast, an inventory of operating and closed landfill sites is required. SCS compiled a database of landfills in the Northeast from various sources and ranked these landfills based on technical criteria presented in Section 4.

METHODOLOGY

SCS' approach to development of the Northeastern U.S. landfill database was as follows:

- Contacted each of the 11 state solid waste regulatory agencies for landfill site listings/information.
- Reviewed the listing of landfill sites in the Northeast published in the "Solid Waste Digest - Northeast Edition," by Chartwell Information Publishers. The Digest identifies active landfill sites, with refuse tipping fees and daily tonnage estimates in five ranges of waste receipts: 1-25 tons per day (TPD), 26-100, 101-500, 500-1,000, and greater than 1,000.
- Reviewed the "U.S. Landfill Directory - Northeastern United States," Solid Waste Management Association of North America (SWANA).
- Incorporated data from the Electrical Power Research Institute (EPRI) sponsored study entitled "Survey of Landfill Gas Generation Potential - 2-MW Molten Carbonate Fuel Cell."
- Reviewed SCS project files on Northeastern landfill sites.

The type of information desired for each prospective landfill site included:

- Landfill name, location, address, contact person, and owner type (public or private).
- Landfill size (acres) and capacity (cubic yards or tons in-place).
- Filling rate in cubic yards or tons/day.
- Average refuse depths.
- Year landfill closed or estimated closure year.
- Presence of an existing (or planned) LFG control or LFG utilization system.

EXHIBIT 3-2. (Continued)

EXHIBIT 5-1. SUMMARY OF CANDIDATE LANDFILLS IN THE NORTHEAST FOR LFG UTILIZATION

State	Number of Landfills	Candidate Landfills	Existing LFG Utilization Projects	Planned LFG Utilization Projects	Remaining Candidate Landfills	Potential LFG Utilization Projects
Connecticut	51	14	1	1	12	9 *
Delaware	6	4	0	1	3	3
Massachusetts	109	28	1	9	18	14 *
Maryland	57	26	3	2	21	16 *
Maine	23	5	0	0	5	5
New Hampshire	43	7	2	2	3	3
New Jersey	27	20	5	5	10	8 *
New York	146	46	16	2	28	21 *
Pennsylvania	59	48	8	2	38	28 *
Rhode Island	9	1	1	0 **	0	0
Vermont	46	8	2	0	6	5 *
Total	**576**	**207**	**39**	**24 (25**)**	**144**	**112**

Notes:

(*) For the States noted (*), the candidate number of landfills were reduced by 25 % to account for potential database errors.

(**) Rhode Island - a second utilization project is planned for the Central Landfill.

EXHIBIT 3-2. (Continued)

CANDIDATE LANDFILLS IN THE NORTHEAST

The results of our survey efforts are summarized in Exhibit 5-1 and presented in Appendix A-1. SCS had intended to rank the sites by technical criteria such as:

- Minimum refuse tonnage in-place - 1,000,000 tons.
- Minimum average refuse depth - 40 feet.
- Minimum acreage - 20 acres.
- Open versus closed landfills.
- Landfills with existing LFG control systems (i.e., wellfields and blower/flare stations).

For many landfills, the location and contact information was the only data available. Due to the limited amount of available data, SCS was able to rank the site on only two criteria:

- Acreage of 20 acres or more.
- Daily waste receipts of 100 TPD or more.

The survey results are presented alphabetically by state with the candidate LFG utilization sites listed first and the non-candidate sites afterwards. The following data is presented for each site:

- Landfill site name, location, address, phone number, contact person, and ownership (public or private).
- Landfill acreage.
- Estimated In-place refuse tonnage.
- Daily waste flow in TPD or one of the five waste flow ranges.
- Estimated landfill closure year.
- Estimated years landfill will remain open.
- LFG features of the landfill - Landfills with existing LFG control systems or flares, existing LFG utilization projects, or planned LFG utilization projects.

Due to the limitations in data sources, we do not have a high level of confidence in the accuracy of the data fields presented. However, this presentation serves as a good starting point in the development of a landfill resource database.

EXHIBIT 3-2. (Continued)

As summarized on Exhibit 5-1, 576 landfills were identified in the 11 Northeastern states. 207 of these landfills passed the technical criteria above as candidate sites. Of these 207 landfills, 39 sites have operating LFG utilization projects with an additional 25 projects in various stages of development. This leaves 144 landfill sites that may be candidates for a LFG utilization project.

Due to the uncertainties in the data, SCS discounted the number of candidate sites in order to estimate the LFG-to-energy potential in the Northeast. For the states with 6 or more candidate sites, SCS assumed 3/4 of the sites would be candidates with the remaining 1/4 unsuitable. Based on this approach, 112 sites were considered potential sites for LFG utilization projects. Together with the 25 projects under development, 137 additional utilization projects have potential for development in the Northeast. These sites should be the focus in exploring potential LFG utilization projects. Recommendations to improve the candidate landfill database are provided in Section 7.

LFG-TO-ENERGY POTENTIAL IN THE NORTHEAST

SCS has estimated the LFG-to-energy potential in the Northeast. Thirty-six of the existing 39 Northeast LFG utilization projects generate electricity. The total electrical generation capacity is approximately 96 MW (from Exhibit 2-5). The average electrical generation project is 2.7 MW (96 MW divided by 36 projects). The three other facilities recover approximately 17 MM cfd of LFG and sell it as is or upgrade it to pipeline quality gas.

Assuming that new projects will have the same average generating capacity (2.7 MW) as existing projects, the 137 candidate landfill sites could generate 370 MW of electrical power under favorable economic conditions. The total electrical generation potential for the Northeast would be approximately 466 MW.

EXHIBIT 3-2. (Continued)

SECTION 6

LANDFILL GAS MODELS

LFG GENERATION MODEL

Computer models often are used to estimate LFG generation and collection quantities. For this report EPA's NSPS emissions model was used to estimate LFG generation quantities over time. SCS modified this model to estimate LFG collection quantities and the economics of LFG utilization. Additional background information regarding the LFG generation models is available in EPA's "Air Emissions from Municipal Solid Waste Landfills -- Background Information for Proposed Standards and Guidelines." [18]

This model is based on a first-order decomposition model, which estimates the LFG generation rate using two parameters: Lo, the potential methane generation capacity of the refuse, and k, the methane generation decay rate, which accounts for methane generation rate decreases as the solid waste decomposes. The methane generation rate is assumed to peak upon placement of the refuse in the landfill. This model provides an opportunity to enter Lo and k values using default values or test data. [23]

SCS entered the model into the "Baler" software which allows for its general use. The model guides the user through the required input fields and allows for selection of three output reports. Copies of the model input screens are provided in Appendix B.

Many of the input fields have preselected default values as the starting points for a site analysis. The user should modify these defaults with site or project specific data. The model inputs and default values are discussed below:

- Landfill name and location.
- First year of refuse filling (yr).
- LFG generation constant (k) - the default value is <u>0.05 yr^{-1}</u>. EPA reported that k values range from 0.003 to 0.21 from both theoretical models using field test data and from actual field test measurements. [23]
- Methane generation potential (Lo) - the default value is <u>170 cubic meters per Mg (cm/Mg)</u>. EPA reported Lo value ranges from approximately 6 to 268 cm/Mg. [23]
- LFG collection efficiency - the default value is <u>50 percent</u>. This value is dependent upon site conditions, LFG collection system configuration, final cover system, etc.
- Refuse filling history by year (tons) - input the annual waste receipt data by year.

Based on the above inputs, LFG generation and collection quantities are estimated for a 50 year period in units of millions of cubic feet of LFG per year (MM cf/yr).

LFG UTILIZATION ECONOMIC MODEL

<u>Model Assumptions</u>

EXHIBIT 3-2. (Continued)

SCS developed an economic model to perform a preliminary assessment of the economics of generating electricity for utility sale. The electrical generation facility is sized based on the LFG collection quantities estimates over a 10-year period. Estimates of revenues, capital and operating costs, and other payments are made. A discussion of user inputs and default values follow:

Power Plant Sizing and Performance--

- Year Commenced Commercial Operation (yr) - calendar year facility on-line.
- Methane Content (%) - default value is 50 percent methane.
- Engine Generator Heat Rate (Btu/kWh) - the default heat rate is 11,500 Btu/kWh (typical for a Caterpillar 3516 engine generator).
- Plant Capacity Based on 10 Year LFG Flowrate (kW) - the model calculates the generating capacity based on the average LFG flowrate over the first 10 years of commercial operation. The engine generator sizing is based on the heat rate.
- Power Plant Sizing Adjustment (%) - the default value is 90 percent. This adjustment allows the user to reduce the power plant size to provide excess capacity and limit potential LFG shortfalls in future years.
- Power Plant Capacity (kW) - the model will calculate the plant sizing by multiplying the two above fields (rounded down to the nearest 100 kW).
- Parasitic Loads (%) - percent of Power Plant Capacity required to support on-site plant requirements. Default value is 6 percent.
- Plant Availability (%) - percent of the time the plant is on-line. Default value is 85 percent.

Utility Revenue Rates--

- 1st Year Energy Sales Rate ($/kWh) - initial year's annual electrical sales rate for energy payments only. Capacity payments should be separately entered. The example uses an energy sales rate of $0.04/kWh. Typical rates in the Northeast are less than $0.04/kWh. Sometimes when capacity payments are combined with energy sales into a single rate, values of $0.04/kWh or higher may be obtained.
- Electric Rate Escalation (% per year) - percent increase per year in energy payments rate.

EXHIBIT 3-2. (Continued)

- Capacity Payment Rate ($/kW/yr) - the value of the capacity payments per kW per year based on the project's contract term. Utilities often have varying capacity payments dependent upon the length of the contract, i.e., longer term contracts (20 years) receive higher capacity payments per kW per year. The default value is $0/kW/yr.

Capital Cost Estimates--

- Power Plant Capital Cost ($) - estimated power plant capital cost. The default value is $1,000 per kW of plant capacity previously calculated.

- Landfill Acreage (acres) - landfilled area only, not total site acreage. The example is for a 20 acre site.

- LFG Collection System Capital Cost ($) - the default value is $10,000 per acre of landfill fill area. Enter ($0) if the landfill owner is responsible for installation of the LFG collection system.

- Total Capital Cost ($) - sum of Power Plant Capital Cost and the LFG Collection System Capital Cost.

Annual Costs/Payments--

- O&M Cost - Wellfield ($) - default value is 10 percent of the LFG Collection System Capital Cost. The example value was 12 percent because the example is a small project.

- O&M Cost - Plant ($) - default value is $0.015 per kWh of electricity sold.

- LFG Condensate Disposal ($) - default value is zero.

- Other Annual Costs (Administration, Insurance, Engineering, Etc.) ($) - default value is 2 percent of the Total Capital Cost.

- O&M Escalation Rate (%) - use inflation rate as default.

- Inflation Rate (%) - default value is 3 percent.

- Section 29 Tax Credit Value ($/MMBtu) - $0.979/MMBtu - this is the calendar year 1993 rate. The future year tax credit value is automatically increased by the annual inflation rate. Tax credits are valued through the year 2007.

- Renewable Energy Production Incentive ($/kW) - $0.015/kWh - the future year REPI payment value is automatically increased by the inflation rate each year. Payments are for a maximum of 10 years.

The same unit costs for capital and O&M costs are used in this model, regardless of project size.

EXHIBIT 3-2. (Continued)

Project Ownership Scenarios

The model uses four project ownership scenarios, as follows:

Case I - Public Ownership--

Assumes a municipality owns the landfill and develops the project.

Case II - Private Ownership with Section 29 Tax Credits--

Assumes a LFG developer would develop and own the project. Section 29 tax credits are included as revenues through the year 2007.

Case III - Public Ownership with REPI Payments--

Assumes the municipality develops the project and is eligible to receive the REPI payments for a 10-year period.

Case IV - Public/Private Partnership - with Section 29 Tax Credits and REPI Payments--

Assumes the LFG developer and municipality jointly develop the project. The Section 29 tax credits and REPI payments are both included as income streams.

For each of the above cases, model inputs include:

- Public Financing Interest Rate (%) - default is 6 percent.
- Amortization Period (yrs) - default is 10 years.
- Private Financing Interest Rate (%) - default is 9 percent.
- Royalty to Landfill Owner (%) - default is 5 percent of total revenues.

Economic Model Results

A sample model run for the XYZ Landfill is presented in Exhibits 6-1 through 6-4. The model outputs are as follows:

- Exhibit 6-1. Landfill Gas Generation and Collection - presents LFG generation model inputs, refuse filling history, and LFG generation and collection estimates by year.
- Exhibit 6-2. Assumptions for LFG Utilization Economics - presents assumptions for the economic analysis including utility revenues, plant sizing requirements, capital and annual costs/payments, etc.
- Exhibit 6-3. LFG Production Model - graphical presentation of the LFG generation and collection quantities per year. The estimated fuel consumption for a 15-year operating life is shown. As indicated, there is a LFG shortfall in the final years.
- Exhibit 6-4. LFG Utilization Economics - presents a cash flow analysis for a 15-year project life. Most LFG developers retire the debt service payments within 10 years.

EXHIBIT 3-2. (Continued)

> Higher profits typically are realized after debt service is retired as shown by the improved returns in the last 5 years.

The cash-flow model results are presented in Exhibit 6-4. For each case, the analysis presents the debt service, net income, debt coverage ratio, and simple payback over a 15-year project life. Each case is discussed below for the XYZ Landfill example:

Case I - Publicly Owned and Operated Project--

Assumes the landfill owner (a municipality) would develop and own the project. Annual revenues, assuming no Section 29 tax credits or REPI payments, are projected to be approximately $149,000. Operating costs are $94,000. With a debt service of $95,000, the project would have a net loss of $40,000 the first year, and these losses would continue until year 11 when the debt has been repaid. The year 11 profit is $74,000.

Case II - Project Cash Flow With Section 29 Tax Credits — LFG Developer Owned and Operated Project--

Assumes a LFG developer would develop the project and could fully utilize the Section 29 tax credits. This analysis treats the tax credit as additional income and does not examine other tax benefits related to depreciation or corporate tax rates.

As shown, the project return improves. However, based on the developer's 25 percent equity investment and his borrowing the balance of the required capital, the project has a small profit of $10,000 after debt service. The debt coverage ratio of 1.13 is too low to support the project.

Case III - Project Cash Flow With REPI Payments (without Section 29 Tax Credits) — Publicly Owned and Operated--

This analysis uses the same assumptions as Case I with the addition of REPI payments. If the REPI program was fully funded for the 10-year period as authorized, the project shows a first year profit of $17,000 and a 6.2 year payback period.

Case IV - Project Cash Flow With Section 29 Tax Credits and REPI Payments — Public/Private Partnership--

A project structured to take advantage of both the tax credits and REPI payments would have an even larger return. In this case, the municipality would finance 75 percent of the capital cost with the developer providing 25 percent of the equity. The net income after debt service for the first year is estimated at $64,000 with a 5.2 year payback period.

> The ability to structure a project to use both of these programs is unknown. In addition, the REPI payments are subject to appropriation by Congress and may not be guaranteed for the full 10 years of the program. This scenario is considered to be a best-case.

EXHIBIT 3-2. (Continued)

LIMITATIONS

Both the LFG generation model and economic pro-forma are based on "rule-of-thumb" assumptions and conditions. These models are intended as a preliminary screening tool. Actual LFG quantities and project economics will may vary considerably from these model results. Landfill characteristics and project costs vary geographically, are dependent on technologies selected, regulatory requirements, energy revenues, royalties, etc.

EXHIBIT 3-2. (Continued)

EXHIBIT 6-1. LANDFILL GAS GENERATION AND COLLECTION

EXHIBIT 3-2. (Continued)

EXHIBIT 6-2. ASSUMPTIONS FOR LFG UTILIZATION ECONOMICS

EXHIBIT 3-2. (Continued)

EXHIBIT 6-3. LFG GENERATION MODEL

EXHIBIT 3-2. (Continued)

EXHIBIT 6-4. LFG UTILIZATION ECONOMIC ANALYSIS

EXHIBIT 3-2. (Continued)

EXHIBIT 6-4. (Continued)

EXHIBIT 3-2. (Continued)

EXHIBIT 6-4. (Continued)

EXHIBIT 3-2. (Continued)

EXHIBIT 6-4. (Continued)

EXHIBIT 3-2. (Continued)

EXHIBIT 6-4. (Continued)

EXHIBIT 3-2. (Continued)

SECTION 7

AREAS FOR FUTURE STUDY

This study has identified the challenges facing the LFG utilization industry and approaches for overcoming these challenges. The challenges include overcoming the economic, institutional and regulatory barriers. With many landfill owners faced with increasing regulatory requirements to control LFG emissions, economic use of the LFG is becoming increasingly important in order to reduce the overall landfill management costs.

Through the course of the project, SCS identified activities to further encourage implementation of LFG recovery projects in the Northeast. Several of these suggested activities resulted from a presentation in Boston (February 1994) to state regulatory and energy policy representatives. Potential activities include:

1. Develop a more complete and reliable landfill database. Refine the list of candidate landfills in the Northeast, and verify and provide additional information about these sites (beyond what was included in this report).

2. Identify end uses for the LFG at candidate sites. Of particular interest are landfill sites located near large consumers of natural gas or fuel oil which could use the LFG as a replacement fuel.

3. Prepare case studies of successful LFG projects of varying sizes. The objectives of such case studies would be to:

   - Describe success stories that could be followed.
   - Educate institutional participants.
   - Public relations purposes.

   Small LFG utilization projects require special emphasis. Project case histories are needed which show how LFG supplied energy has been used to satisfy landfill facility energy requirements (i.e., leachate pumping and treatment, building heat and power, incineration of contaminated soils, etc.).

4. Prepare a guideline document for use by state environmental agencies in reviewing permit applications for LFG recovery projects. As an adjunct to such a project, training sessions could be sponsored on the use of the guidance document and conduct of the review process.

5. Provide a training course(s) regarding use of the LFG models (included in the report) for estimating LFG generation and recovery, electrical production, and economics of LFG utilization.

6. Conduct outreach seminars - to educate landfill owners, regulators, etc., on LFG and to encourage development of utilization projects. Seminars could be regional and/or state focus. Encourage co-sponsorship by solid waste associations (SWANA, EIA), regulatory agencies, economic development authorities, etc.

EXHIBIT 3-2. (Continued)

7. Develop "Fact Sheets" for distribution to specific audiences concerning LFG. Targeted audiences could include:

   - Landfill 0wners - inform them of LFG liabilities and opportunities.

   - LFG Developers - identify candidate sites, especially where there is a potential for direct use of the LFG as a replacement fuel.

   - Utilities/Energy Users - inform them of the project benefits and resources available within their service territories.

   - Regulatory Agencies (solid waste, air, PUCs) - inform them of measures they can take to lower regulatory barriers and thereby encourage LFG use.

   - Financial Investors - inform them of the industry's successful project financing methods, performance track record, and benefits.

   - Legislators - inform them of the value of this energy resource, economic development benefits, reduced environmental compliance costs to their constituents, etc.

8. Work with EPA and state regulatory agencies in obtaining offset emission credits, etc.

9. Investigate ways to encourage construction of high energy-consuming industrial facilities near landfill sites so that they can utilize the available LFG as a low-cost energy source.

EXHIBIT 3-2. (Continued)

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