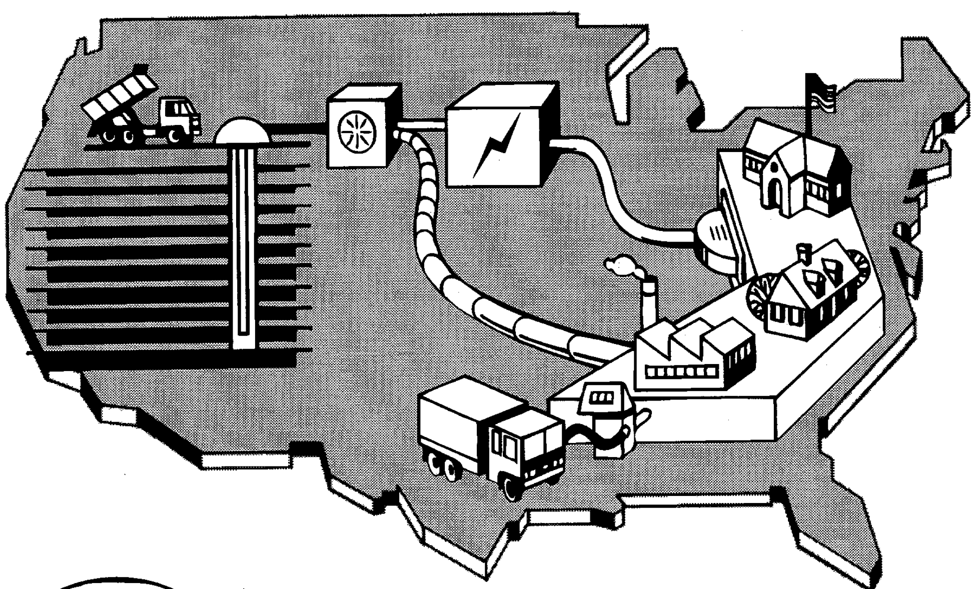
United States Environmental Protection Agency
Office of Air and Radiation (6202J)
EPA 430-K-99-002
January 1999

EPA

Landfill Gas-to-Energy Project Opportunities

Background Information on Landfill Profiles



EPA
LANDFILL METHANE OUTREACH PROGRAM

EPA Landfill Methane Outreach Program

LANDFILL METHANE OUTREACH PROGRAM

The EPA Landfill Methane Outreach Program, a key component of the United State's *Climate Change Action Plan*, encourages the use of landfill gas (LFG) as an energy resource. EPA assists utilities, municipal and private landfill owners and operators, tribes, and state agencies in reducing methane emissions from landfills through the development of profitable landfill energy recovery projects. Methane captured from landfills can be transformed into a cost-effective fuel source for electricity, heat, boiler and vehicular fuel, or sale to a pipeline. EPA estimates there are approximately 200 landfill methane recovery projects in the U.S. and that up to 750 landfills could install economically viable landfill energy projects.

The Landfill Methane Outreach Program includes five important components: the State Ally, Energy Ally, Industry Ally, Community Partner, and Endorser programs. EPA establishes separate alliances with state agencies, energy providers (including investor-owned, municipal and other public power utilities and cooperatives), key trade and public sector associations, members of the landfill gas development industry (including developers, engineers, equipment vendors, and others) and local communities, municipalities and landfill owner/operators through a Memorandum of Understanding (MOU). By signing the MOU, each Ally/Partner acknowledges a shared commitment to the promotion of landfill gas-to-energy recovery at solid waste landfills, recognizes that the widespread use of landfill gas will reduce emissions of methane and other gases, and commits to undertake activities to enhance development of this resource. In return, EPA agrees to provide landfill gas-to-energy project assistance and public recognition of the Allies' and Partners' participation in the program.

Landfill Gas-to-Energy Project Opportunities

Background Information on Landfill Profiles

Prepared For:

U.S. Environmental Protection Agency
Atmospheric Pollution Prevention Division
401 M Street, SW
Washington, DC 20460

Prepared By:

ICF Incorporated
Washington, DC

Acknowledgments

ICF Incorporated prepared this document under U.S. Environmental Protection Agency Contract 68-W7-0069, Task Order 008. The principal authors of this document were Diana Pape, Elizabeth O'Neil, and Jennifer Kish of ICF Incorporated. The authors would like to thank Ed Coe of EPA-APPD for his management and guidance during the preparation of this document.

Table of Contents

List of Exhibits

Acronyms and Terms

Btu	British thermal unit
cf	cubic feet
CH_4	methane
CO_2	carbon dioxide
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
GW	gigawatt (1 billion watts)
GWh/yr	gigawatt hours/year
GWP	Global Warming Potential
hr	hour
IC	internal combustion
kW	kilowatt (1,000 watts)
kWh	kilowatt hour
LFGTE	landfill gas-to-energy
LMOP	Landfill Methane Outreach Program
m^3	cubic meters
mmBtu	million Btu
mmscf/d	million standard cubic feet per day
mmscf/yr	million standard cubic feet per year
MOU	Memorandum of Understanding
MSW	municipal solid waste
MW	megawatt (1 million watts)
NA	not available
NARUC	National Association of Regulatory Utility Commissioners
NMOC	non-methane organic compound
NOx	nitrogen oxides
PUC	Public Utility Commission
REPI	Renewable Energy Production Incentive
scf/d	standard cubic feet per day
SO_2	sulfur dioxide
tpy	tons per year
VOCs	volatile organic compounds
WIP	waste-in-place
yd^3	cubic yards
yr	year

1. Introduction

1.1 Purpose

The U.S. Environmental Protection Agency estimates that approximately 200 landfill methane recovery projects exist in the United States and that up to 750 economically viable landfill gas-to-energy projects could be developed; these potential projects are constrained by informational, regulatory, and other barriers. Through the Landfill Methane Outreach Program (LMOP), the EPA is working to overcome these barriers and encourage the benefits of developing landfill gas-to-energy projects. A key objective of the LMOP is to provide landfill owners and operators, developers of landfill gas-to-energy projects, utilities, and other potential project participants with information on landfills that may offer attractive energy development opportunities.

Since 1994, U.S. EPA's Landfill Methane Outreach Program (LMOP) has participated in an ongoing effort to gather information on Municipal Solid Waste landfills (MSW). This document describes the methodology used to develop the state-specific landfill profiles and the economic and environmental benefits of using landfill gas as an energy source. The state-specific profiles are contained in the document entitled, *Landfill Gas-to-Energy Project Opportunities, Landfill Profiles for the State of [STATE]*. EPA has developed landfill profiles for 31 states: Alabama, California, Colorado, Connecticut, Florida, Georgia, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maryland, Massachusetts, Minnesota, Missouri, Nebraska, Nevada, New Jersey, New York, North Carolina, Ohio, Oklahoma, Oregon, Pennsylvania, Tennessee, Texas, Utah, Virginia, Washington, and Wisconsin. Profiles are available from EPA's Landfill Methane Outreach Program, Atmospheric Pollution Prevention Division, Office of Air and Radiation. For more information call 1-888-STAR-YES.

1.2 Landfill Classification

Compiling information on MSW landfills is a first step in determining the potential for developing landfill gas recovery projects and can also serve to address informational barriers by providing details about specific candidate landfills to organizations that may be interested in developing such projects. It does not, however, include a detailed technical and economic analysis of each site, a critical step in determining whether developing a landfill gas-to-energy recovery project at a particular site is feasible.

To facilitate the use of available landfill information, EPA has categorized the landfills into five categories: Current Project,[1] Candidate Project, Shutdown, Other, and Unknown Waste-In-Place (WIP). This characterization is based on the status of the landfills' landfill gas-to-energy project(s) and is intended to facilitate identification of project opportunities. This characterization scheme is based on the generation of methane which is a function of many factors, the most critical being the amount of waste-in-place and the number of years the waste has been in the landfill. Therefore, the longer a landfill has been closed, the less attractive it becomes for methane recovery. Landfills closed prior to 1993 generally have a low probability

[1] Current projects illustrate the wide range of successful project development options.

of generating enough methane to make a gas recovery project economical, and, consequently, to be categorized as a candidate landfill, the landfill must be in operation or closed after 1993. Exhibit 1-1 presents the criteria used to catagorize the MSW landfills.

Exhibit 1-1. Criteria Used to Catagorize Landfills

Current Project:
- ❑ Landfill with operational LFGTE project; or
- ❑ Landfill with LFGTE project under construction.

Candidate Project:
- ❑ Landfill does not currently have a LFGTE utilization project and the status is reported as ‘potential’ or ‘planned’; or
- ❑ Landfill is currently operating or closed after 1993, and has more than 1,000,000 tons of methane generating waste-in-place.[a,b]

Shutdown:
- ❑ Landfill has a shutdown LFGTE project.

Other:
- ❑ Landfill has less than 1,000,000 tons of methane generating waste-in-place with no current or planned LFGTE project.

Unknown WIP:
- ❑ Landfill where insufficient data are available to determine the waste-in-place.

[a] Methane generating WIP is WIP over the past 30 years of operation.

[b] By modeling the relationship between WIP and methane generation, a cut-off of 1,000,000 tons of WIP was established; landfills having at least 1,000,000 tons of WIP are considered Candidate Project landfills.

The following information briefly describes the organization and content of the remainder of this document.

Sections 1.3-1.4: Background Information on Gas Collection and Use. These sections contain background information on the generation, collection, and utilization of landfill gas. Section 1.3 discusses the composition and characteristics of landfill gas, and the utilization of landfill gas as an energy source for various applications. Section 1.4 discusses the benefits of landfill gas-to-energy projects to specific groups, and project opportunities for landfill owners and operators, industrial end users, and utilities.

Section 2: Data Collection Methods. This section describes the methodology used to collect data from state and local sources, and the national databases used to generate the profiles. The landfill screening process and a summary table of database sources are also discussed in this section.

Section 3: Landfill Profiles Definition of Data Fields. This section provides definitions of the data fields included in the landfill profiles. Each data field is defined and, where applicable, calculations and default values used to derive estimates are provided. The section is organized according to the five sections that comprise the landfill profiles: General Landfill Information, Landfill Gas Collection, Landfill Gas Utilization, Environmental Benefits of Utilization, and Contact Information. A sample profile sheet is provided at the end of Section 3.

1.3 Background Information

This section provides general background information on landfill gas generation, collection, and utilization. This section further discusses landfill gas-to-energy (LFGTE) project gas utilization options, gas delivery systems and electric power generation. For more detailed information, a number of additional sources are available, including *Turning a Liability into an Asset: A Landfill Gas-to-Energy Handbook for Landfill Owners and Operators* (U.S. EPA, 1994) and *Opportunities to Reduce Anthropogenic Methane Emissions in the United States: Report to Congress* (EPA, 1993).

1.3.1 Landfill Gas Generation

Landfill gas is produced through the natural process of anaerobic (i.e., without oxygen) decomposition of organic wastes. Typically, landfill gas is composed of about 50 percent methane, 45 percent carbon dioxide, and 5 percent other gases including hydrogen sulfides and volatile organic compounds (VOCs). The primary constituent of natural gas is methane, therefore landfill gas can be used as fuel. Characteristics of the landfill gas, such as quantity of methane per unit of landfill gas and amount of landfill gas generated per unit of waste, are a function of the quantity and type of waste-in-place, climate, and several other site-specific factors.

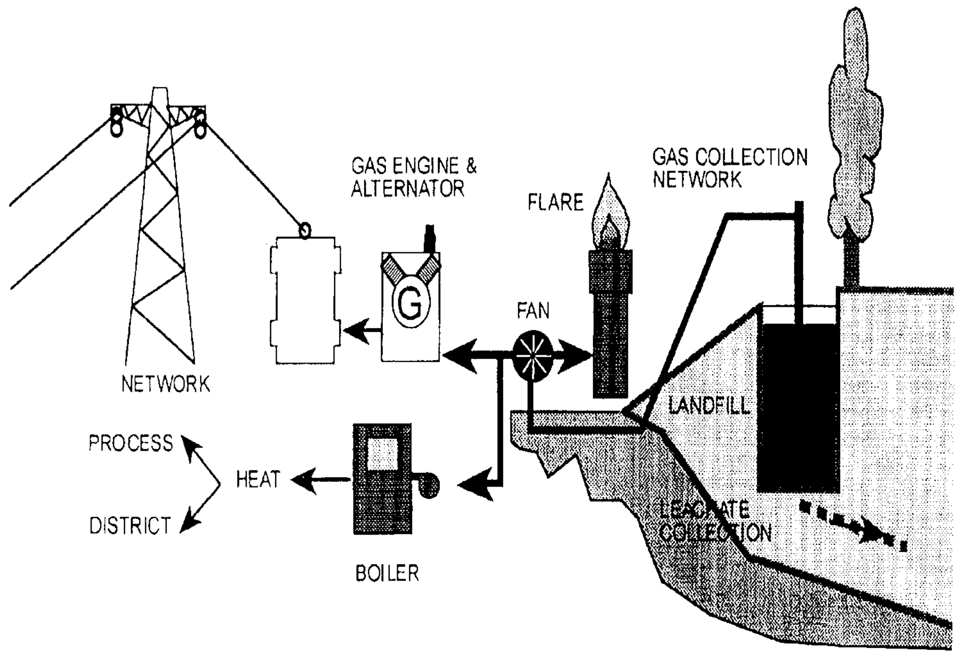
Landfill gas generation is estimated to begin from six months to two years after waste is placed in a landfill. Gas generation rates vary depending on moisture content and other site-specific factors. However, the gas profile for an individual landfill may vary considerably from this trajectory; for example, landfill gas generation may continue at a significantly higher rate than expected for many years after landfill closure depending on site conditions.

Landfill gas generation is often predicted using a first order decay model, which takes into account the changing rate of gas generation described above. However, a simpler model was used for the profiles contained in this report. This model assumes a constant rate of landfill gas generation and, as a result of this difference, the two models may predict different gas generation rates. The model used is explained in greater detail in Chapter 3 of this report.

1.3.2 Landfill Gas Collection

Landfill gas can be collected using a relatively simple system of vertical wells drilled into the landfill at selected points. Well spacing depends on site-specific variables, but typically ranges from 150 to 300 feet. Horizontal trenches can also be used in place of, or in addition to, vertical wells. Horizontal trenches tend to be less durable than vertical wells because refuse added to the top of the trenches can weaken the pipes and cause breakage. All of the wells (or trenches) are connected by horizontal piping to a central point where a motor/blower provides a vacuum to remove the gas from the landfill. In an effectively designed and constructed system, methane recovery efficiencies in excess of 85 percent can be achieved (Maxwell, 1990). Exhibit 1-2 presents a schematic of landfill gas-to-energy recovery systems.

Exhibit 1-2. Schematic of Various Landfill Gas-to-Energy Recovery Systems



Collection systems are usually operated as part of an overall landfill gas control system. In many cases, a collection system is necessary to suppress landfill odors or control gas migration that, if left unchecked, could create potential safety hazards.

In addition, under the Clean Air Act, Title 40CFR, Part 60 Subparts WWW and Cc, New Source Performance Standards (NSPS) and Emissions Guidelines (EG) for Municipal Solid Waste (MSW) Landfills, require many landfills to install gas collection systems in order to reduce emissions of non-methane organic compounds (NMOCs). EPA's New Source Performance Standards and Emission Guidelines (i.e., the Landfill Rule) were promulgated on March 12, 1996 and amended June 1998. NSPS affects “new landfills” that commenced construction, modification or reconstruction on or after May 31, 1991. EG affects “existing landfills” that commenced construction, modification, or reconstruction before May 30, 1991.

The compliance requirements for NSPS and EG are essentially the same. If the landfill has a total permitted capacity below 2.5 million megagrams of waste or 2.5 million cubic meters of waste, the landfill is exempt from further evaluation. If the landfill is above the design capacity threshold, 2.5 mmg and 2.5 million cubic meters of waste, then the landfill’s annual non-methane organic compound emissions (NMOC) must be determined. If the NMOC emissions are greater than or equal to 50 MG/yr the landfill must adhere to the NSPS or EG requirements. These requirements include submitting compliance reports, installing a gas collection system, destroying the landfill gas at 98 percent efficiency, and adhering to specified operation and maintenance procedures. For further information on the NSPS or EG, please see the EPA LMOP document, *Helping Landfill Owners Achieve Effective, Low-Cost Compliance with Federal Landfill Gas Regulations Document*, December 1998.

1.3.3 Landfill Gas Utilization

Once collected, landfill gas can be used as an energy source for many different applications, including electricity generation, space heating and cooling, industrial processes, and vehicle fuels. In addition, landfill gas can simply be flared when a cost-effective utilization option cannot be developed. In each of these options, the methane contained in the recovered landfill gas is consumed, either through combustion (e.g., use as a fuel, including upgrading to pipeline quality gas and flaring) or conversion to a non-greenhouse gas, thereby reducing emissions of methane to the atmosphere. Moreover, using landfill gas to generate electricity can displace other fossil fuel use, thereby reducing emissions of carbon dioxide and other local air pollutants.

As mentioned previously, approximately 200 fully operational landfill gas recovery and utilization projects exist in the U.S., with over 58 additional projects under development (LMOP, 1998). Landfill gas-to-energy projects have established a track record that demonstrates the reliability and economic viability of landfill gas recovery and utilization technology. Electric power generation is the most common gas utilization method for landfill gas recovery projects. In fact, more than 78 percent of the planned or operational landfill energy projects generate electricity, while about 18 percent sell medium-Btu gas to a direct user, 3 percent upgrade their gas to pipeline quality, and approximately 1 percent use landfill gas in leachate and condensate disposal systems (Thorneloe, 1997). The electricity generating capacity of landfill gas projects typically ranges between 0.5 and 4 megawatts (MW), with the largest operational facility generating almost 50 MW. Total U.S. installed electric capacity fired by landfill gas is roughly 520 MW (Thorneloe, 1997). In addition, current landfill gas sales displacing fossil fuels are equivalent to 140 MW of generating capacity (Thorneloe, 1997).

The following is a brief summary of landfill methane utilization options. For more information on these technologies and their costs, see EPA, *Turning a Liability into an Asset: A Landfill Gas-to-Energy Handbook for Owners and Operators* (U.S. EPA, 1994).

Electricity Generation. For landfills that generate significant amounts of landfill gas (i.e., more than 1.3 million cubic feet per day), electric power generation can be a cost-effective method of utilization. Several proven technologies can be used to generate electricity from landfill gas.

- ❑ **Reciprocating Internal Combustion Engines (IC).** These engines have proven to be cost-effective in many applications, and, in the case of small landfills, may be the only available, proven generating option. IC engines are currently in use at about 89 sites (Thorneloe, 1997), with typical engine sizes ranging from 250 kilowatts (kW) to 1 MW in size (more than one engine can be installed at a single site, and a typical project's total generating capacity is 3 to 4 MW). The three primary manufacturers of these engines have modified their designs and operating procedures to make the engines "landfill-gas-adapted."

- **Gas Turbines.** Although gas turbines have higher capital costs than IC engines per kilowatt of installed capacity, at larger landfills, gas turbines have a lower cost of electricity (i.e., ¢/kWh). The cost per kW hour of the generating capacity drops as gas turbine size grows, requiring a reliable gas flow of approximately 2 million standard cubic feet per day (mmscf/d) in order to be economically feasible. This corresponds to a generating capacity of at least 3 to 4 MW. Although they require higher gas flows, gas turbines have a number of advantages over IC engines. Because of the large quantities of excess air, NO_X emissions are considerably lower than from IC engines. In addition, gas turbines have continuous combustion which better adjusts to fluctuations in heat values of the landfill gas fuel. Furthermore, the alloys used in turbines tend to be more resistant to corrosion from impurities within the gas supply. There are about 22 landfill gas projects in the U.S. using gas turbines (Thorneloe, 1997).

- **Rankine Cycle (Steam) Turbines.** In rare cases where gas flow rates are extremely high, a rankine cycle turbine may be used. If the scale of the operation will support a rankine cycle turbine, high electrical efficiencies can be achieved with lower emissions of air pollutants and lower costs per kWh of output. Steam turbines also produce large amounts of high temperature water that can be easily utilized for thermal co-generation activities. The smallest facilities usually generate at least 8 to 9 MW of power. Currently, rankine cycle turbines are only used at approximately five of the landfills in the U.S., the largest being a 47 MW facility at Puente Hills, California (Thorneloe, 1997).

- **Combined Cycle Engines (gas turbine and steam turbine).** Combined cycle engines offer the highest efficiency and cost effectiveness for large landfills. These engines are used in the independent power industry for power plants over 20 MW. Currently, only two facilities have operational combined cycle engines, but the capacity of both operational and in construction facilities is about 55 MW (Thorneloe, 1997).

- **Gas Delivery Systems.** Gas processing and delivery systems process landfill gas so it can be sold as a gaseous fuel. The fuel can be delivered directly to a customer via dedicated pipes or to the natural gas pipeline network. The two main options include:

  — **Sale as a Medium-Btu Fuel.** Landfill gas can be used for a variety of industrial and commercial applications, such as firing boilers and space heating, and can also be co-fired with other fuels. Medium-Btu gas can be economically transported via dedicated pipelines to one or more industrial facilities. An ideal medium-Btu gas customer is located within 5 miles of the landfill and has constant demand for gas. Currently, 27 landfills have medium-Btu gas projects that produce approximately 44 mmscf/day (Thorneloe, 1997).

  — **Sale as a High-Btu Fuel.** Landfill gas can be upgraded to a high-Btu fuel and sold directly to natural gas companies. The cost to upgrade the gas to pipeline quality is generally very high, as the process involves the removal of water, carbon dioxide (CO_2), hydrogen sulfide (H_2S), hydrocarbons, and on some occasions, nitrogen. In addition, sale as a high-Btu fuel to a pipeline usually requires that a natural gas pipeline be located within close proximity of the site. Currently, there are 5 Btu plants in the United States (Thorneloe, 1997).

- **Emerging Utilization Options.** Other less conventional utilization options for landfill gas are also available or may soon become available. Some of these options, such as fuel cells, have demonstrated advantages over conventional landfill gas-to-energy equipment. Although fuel cells are not in wide commercial production due to costs, they may become more widely used due to advantages including the minimization of emissions, noise, and vibrations through the chemical conversion of landfill gas to electricity. Several landfill owners, operators, and project developers have considered fuel cells for landfill gas application (Thorneloe, 1997). Other options, such as the conversion of landfill gas to vehicle fuel, underway at several landfills, have not been built on a large scale. A small number of landfills have also used recovered gas to incinerate soil contaminated with hazardous waste (Thorneloe, 1997).

1.4 Benefits

This section discusses the many benefits of recovering energy from landfill gas. Landfill gas-to-energy projects provide both direct and indirect benefits to the global environment and local community. Section 1.4.1 discusses general benefits of landfill gas-to-energy recovery projects, and Section 1.4.2 discusses benefits realized by specific groups.

1.4.1 General Benefits

Recovery of energy from landfill gas conveys many important global and local environmental benefits as well as the economic benefits of energy production. For example, landfill gas-to-energy improves the global environment by reducing methane emissions, and provides local environmental benefits by reducing volatile organic chemical (VOC) emissions, as well as displacing other pollutants associated with fossil fuel use. In addition, it provides a secure, low-cost energy supply (an energy supply that is currently wasted) that can reduce dependence on fossil fuels. These benefits are discussed in more detail below.

Environmental Benefits. Landfill gas projects provide both direct and indirect environmental benefits. Direct environmental benefits from utilizing landfill gas include reducing VOC emissions, reducing the risk of global warming, and reducing the odor of pungent decaying waste. Landfill gas contains VOCs, which contribute substantially to ground-level ozone and include air toxins. Without control systems, these compounds are released to the atmosphere as waste decomposes. When landfill gas is collected and burned through flaring or in an energy recovery system, VOCs are destroyed. Energy recovery projects further minimize emissions through optimization of gas recovery in order to maximize economic benefit.

Combusting landfill gas also destroys methane, which is a potent greenhouse gas. Landfill gas is the single largest source of methane emissions in the U.S., contributing almost 40 percent of annual methane emissions. Because of methane's potency and its rapid cycling through the atmosphere, reducing methane emissions is crucial in slowing global warming; a ton of methane emitted into the atmosphere is 21 times more damaging than a ton of carbon dioxide over a 100 year time frame (IPCC, 1995).

The primary indirect environmental benefit of landfill gas-to-energy recovery projects is the displacement of fossil fuels. Generating electricity from oil and coal leads to the emission of carbon dioxide (CO_2), a greenhouse gas, and several pollutants, including sulfur dioxide (SO_2), a major contributor to acid rain. By generating electricity from landfill gas, emissions from fossil fuel use are avoided. Moreover, displacing fossil fuels substantially reduces the production of ash and scrubber sludge.

Energy Benefits. Several energy benefits are associated with utilizing landfill gas. First, because decomposing organic waste continuously produces landfill gas, landfill gas-to-energy recovery projects are a nearly constant source of energy. For example, a landfill that has two million tons of landfilled municipal solid waste (MSW) produces, on average, 1.8 mmscf/day of landfill gas and can generate 2.5 MW of electricity. Second, landfill gas has a variety of applications such as electricity generation and direct use by industries. Third, landfill energy projects add to a community's and utility's fuel diversity, as well as provide valuable experience in renewable energy. Finally, landfill projects can provide important distributive generation benefits typical of demand-side management options. For example, since electricity generated from landfill gas is typically directed to local users, transmission losses from the point of generation to the point of consumption are negligible.

Economic Benefits. Landfill gas provides a low-cost source of renewable energy. In addition, more widespread use of landfill gas as an energy source will create jobs related to the design, construction, and operation and maintenance of these systems and lead to advancements in U.S. environmental technology.

1.4.2 Benefits to Specific Groups

Traditionally, landfill gas has been viewed as a safety hazard and a general nuisance. However, there is now an increasing awareness on the part of landfill owners and operators, project developers, utilities, state and local governments, and others, of the environmental, energy, and economic benefits that can result from recovering the energy value of this gas. Some of the principle benefits for different groups and their potential roles in the development process are highlighted below.

Utilities. Several ways exist in which electric utilities can benefit from the development of landfill gas-to-energy. Examples include:

❑ **Stronger Relations With Key Customer Groups.** Landfill gas-to-energy recovery projects enable utilities to enhance long-term relationships with a variety of customer groups. A utility can add significant value to their service offerings through direct or indirect involvement in landfill gas-to-energy development. Some innovative approaches a utility may wish to consider include participation in projects that directly supply landfill gas as a medium-Btu fuel to industrial or commercial end-users, offering project development assistance to a municipality, or initiating a residential or commercially-oriented green marketing program.

- **Diversified Resource Base.** Landfill gas-to-energy projects offer utilities the opportunity to add dispersed base-load capacity to their current system and to diversify their fuel mix. They also offer a competitive source of renewable energy to utilities.

- **Contribution to Environmental Protection.** By participating in landfill gas-to-energy projects, utilities help prevent local and global air pollution. The EPA Landfill Methane Outreach Program recognizes utilities that work with EPA to identify, explore, and act on the best project opportunities. These utilities gain recognition from EPA as well as greenhouse gas reductions that satisfy Climate Challenge commitments.

Landfill Owners and Operators. Benefits of participating in landfill gas-to-energy recovery projects for landfill owners and operators include:

- **Revenue Creation/Reduction of Regulatory Costs.** Landfill gas projects may be a significant source of revenue generation for landfill owners/operators, depending on the size of the landfill, energy costs, and other site specific factors. Even where projects do not generate profits, they may offset the cost of regulatory compliance. EPA's New Source Performance Standards and Emission Guidelines[2] require many landfill owners and operators to collect and combust their landfill gas. Numerous states already require collection and flaring of landfill gas. Utilizing the collected landfill gas as an energy resource, instead of flaring it, will offer many owners and operators an opportunity to recover some of the regulatory costs, and may generate profit.

- **Reduction of Risk.** Even in low concentrations, methane is explosive and can result in fires and explosions that can imperil both people and property. Regulations promulgated under Subtitle D of the Resource Conservation and Recovery Act require owners and operators of landfills to monitor their facilities for methane levels to reduce the risk of landfill gas explosions. If methane concentrations exceed specified limits, owners and operators are required to take necessary steps to ensure protection of human health. Landfill gas-to-energy recovery projects offer the opportunity to virtually eliminate the risk of injury and property damage by collecting and combusting landfill gas before it can accumulate to dangerous concentration levels within the landfill.

- **Financial Incentives.** Developers of landfill gas-to-energy recovery projects may qualify for a number of financial incentives. The Renewable Energy Production Incentive (REPI), mandated under the Energy Policy Act of 1992, provides a cash subsidy of up to $1.5 cents/ kWh, subject to the availability of appropriations, to publicly owned facilities that generate electricity from renewable energy sources, such as landfills, for the period October 1993 through September 2013. In FY1997, payments to landfill methane projects totaled $1.02 million, a significant increase compared to payments made in FY1994, when they totaled just $0.6 million. For more information contact the LMOP at 1-888-STAR-YES.

---

[2] The final standards and guidelines were published in the Federal Register on March 12, 1996. Amendments to the rule were published in the Federal Register on June 16, 1998.

- **Community Image Enhancement.** Developing a landfill gas-to-energy project will enhance the public perception of landfills in local communities. Landfill projects contribute a valuable resource to local communities and municipalities by providing a reliable and efficient energy source and improving local air quality.

Industrial and Other End-Users. Industrial and other potential landfill gas end-users can benefit from landfill gas-to-energy recovery projects. Facilities with constant energy needs that are located near landfills can lower their fuel costs, improve environmental quality, and enhance their public image by using landfill gas in place of traditional fuels. Specific benefits to industrial and other end-users include:

- **Lower Fuel Costs.** For industrial end-users, a nearby landfill that is collecting its landfill gas can be an inexpensive source of medium Btu fuel or steam.

- **Environmental Benefits.** By using landfill gas, industrial end-users contribute to environmental protection by displacing local air emissions associated with fossil fuel use and reducing emissions of methane.

- **Public Image Enhancement.** Through participation in the development of landfill energy recovery projects, industrial end-users can enhance their public image by mitigating the threat of global warming and contributing to improvements in the local economy and environment.

Municipalities/Communities. Municipalities and local communities can also benefit from landfill gas-to-energy recovery projects. Benefits include:

- **Increased Tax Base.** Municipalities or communities that have a landfill gas project in their area increase their tax base, as well as create new job opportunities.

- **Attract New Industries.** A local energy source may attract new industry to the area. For example, industrial producers that could use large quantities of medium Btu gas might want to locate a plant near the landfill since the landfill could provide a cheap source of energy.

- **Reduction of Air Pollution Emissions and Odors.** VOCs emitted from landfill waste decomposition can endanger human health, particularly for those who work on or live near landfills without a collection system. Landfill gas recovery projects offer an opportunity to greatly reduce this health risk by collecting and destroying these harmful compounds before they escape into the atmosphere. In addition, collection and combustion of landfill gas reduces noxious odors.

1.4.3 Opportunities For Project Participants

As mentioned above, there are numerous benefits from participating in a landfill gas-to-energy project. For each potential project participant, a brief discussion of how to assess opportunities is provided below.

Utilities. Utilities should assess how, in light of rapid restructuring in the energy industry, participating in landfill gas projects can enhance critical business objectives. These business objectives include building stronger relationships with key customer groups, broadening utility's resource base, and realizing substantial environmental benefits. This document can help utilities determine the best opportunities for using landfill gas to help achieve these company objectives. Innovative approaches to consider include: assistance to municipalities that must install gas collection systems to comply with regulations or that have candidate landfills ready for project development; participation in projects that directly provide landfill gas as a medium-Btu fuel to targeted industrial or commercial end-users; and development of new marketing programs, such as green pricing, with landfill gas as part of the energy mix to meet customer demands for cleaner, renewable energy sources. These "value-added" services are effective mechanisms to build stronger, more responsive relationships with key customer groups, while acquiring a competitive renewable resource. Moreover, utilities should consider how landfill gas-to-energy furthers their environmental objectives. By participating in landfill gas-to-energy projects, utilities help improve local and global air quality; receive national recognition from the EPA; and fulfill commitments under the U.S. Department of Energy's (DOE) Climate Challenge Program.

Landfill Owners and Operators. Landfill owners and operators can assess conditions at their sites to determine whether their landfill can support an economically attractive project. If it appears that the landfill has potential for energy recovery, owners and operators can take active roles in determining what project configuration is right for the landfill, identifying potential energy customers, and seeking potential development partners. As necessary during each stage of this process, landfill owners and operators can work with project development experts for guidance in designing a successful and profitable project.

Industrial End-Users. Potential industrial, commercial, or other end-users should assess the potential for reducing energy expenses by using landfill gas in their facilities. These industrial customers can assess project potential by examining conditions at the local landfill and evaluating their current and future energy requirements. If it appears that there is a match between the end-user and the landfill, they can work as partners in project development, potentially involving additional project developers as well.

2. Data Collection Methods

This chapter describes the methodology used to collect data from state and local sources, the national databases used to complete profiles, and the landfill candidacy screening process.

2.1 Methodology Used to Collect Data

In general, a top-down approach was used to gather data, by obtaining the maximum amount of information on all landfills from state records, and then filling and checking in data gaps with information from records at the regional, county, or municipal levels, as well as from published national reports and landfill owners and operators. Data used to produce the landfill profiles were assembled from state and local sources as well as various national solid waste publications. In addition, landfill owners, operators, and project developers regularly provide information on landfills and landfill gas-to-energy projects. Although the landfill profiles are updated regularly, the accuracy of the landfill profile information depends on the quality of information from these various sources.

Data Sources Used to Prepare Landfill Profiles

- ❑ EPA-ORD Landfill Gas Utilization -Survey (Thorneloe, 1997)
- ❑ Directory and Atlas of Solid Waste Disposal Facilities (SWA, 1994)
- ❑ Implementation Guide for Landfill Gas Recovery Projects in the Northeast (SCS, 1994)
- ❑ Landfill Gas-to-Energy 1994-1995 Activity Report (SWT, 1994)
- ❑ Methane Recovery from Landfill Yearbook (GAA, 1994)
- ❑ Project developers, landfill owners, and operators
- ❑ State and local records
- ❑ Survey of Landfill Gas Generation Potential (EPRI, 1992)
- ❑ U.S. Landfill Directory (SWANA, 1992)

In many cases, states did not have data available in a consolidated format (e.g., a database). In these situations, discrete data sources that provided essential data were gathered. When state documents did not provide the level of detailed information necessary to evaluate candidate landfills, regional offices located within each state and/or county or municipal offices were contacted to access information in their files. Landfill owners and operators often presented data for updating current LFGTE Project information.

2.2 Landfill Candidacy Screening Process

To facilitate the identification of landfills that could potentially be considered for LFGTE projects, each landfill is classified into one of five categories:

- ❑ **Current Project.** The landfill currently operates a gas-to-energy recovery project, or is constructing a gas recovery project.

- **Candidate Project.** The landfill does not currently have a LFGTE utilization project and the status is reported as ‘potential or ‘planned; or the landfill is currently operating or closed after 1993 and the landfill has more than 1,000,000 tons of methane generating waste-in-place.

- **Shutdown.** The landfill has a shutdown LFGTE project.

- **Other.** Landfill has less than 1,000,000 tons of methane generating waste-in-place with no current or planned LFGTE project.

- **Unknown WIP.** Landfill where insufficient data are available to determine the waste-in-place.

The categorization scheme is based on the premise that a landfill must be capable of generating a certain amount of methane to make a gas recovery project desirable. The generation of methane is a function of many factors, the most critical being the amount of waste-in-place and the number of years the waste has been in the landfill. Peak methane generation occurs soon after closure. Therefore, the longer a landfill has been closed, the less attractive it becomes for methane recovery. For the purposes of determining Candidate Project landfills, those landfills that ceased accepting waste prior to 1993 were eliminated because they have a low probability of generating enough methane to make a gas recovery project economical. By modeling the relationship between waste-in-place and methane generation, a cut-off of 1,000,000 tons of waste was established; landfills having at least 1,000,000 tons of waste-in-place were considered Candidate Project landfills.

An alternative application of landfill gas -to-energy, particularly for smaller landfills that are not considered Candidate Project landfills for the purpose of this document, is the local use of landfill gas for niche applications such as the heating of greenhouses. Where these applications are viable, they may be the most economically attractive for landfills that have less than 1,000,000 tons of waste-in-place. For more information contact the EPA’s STAR hotline, 1-888-STAR-YES.

The following three steps describe the landfill candidacy screening process for determining Candidate Project Landfills.

Step 1: Evaluate the Reported Status of the Landfill Gas-to-Energy Project.

If the reported utilization system status of the landfill gas-to-energy project is current or under construction, the landfill is classified as current.

If the reported utilization system status of the landfill gas-to-energy project is ‘planned’ or ‘potential’ the landfill is classified as candidate.

If the reported utilization system status is shutdown the landfill is classified as shutdown.

Step 2: Determine the 1998 Waste-in-Place (WIP).

Waste-in-place data were examined for all active landfills and inactive landfills. Additional screening was performed to determine if the landfill had 1,000,000 tons of methane generating waste-in-place.

Landfills with less than 1,000,000 tons of methane generating waste-in-place were classified as other. Landfills with insufficient waste-in-place data were classified as unknown WIP.

Some states do not collect the total amount of waste-in-place at each landfill. Instead, the state may have on file annual acceptance rates, open years, landfill acreage and depth, daily acceptance rates, and number of days operating per week. From different combinations of these data elements, a value for the landfill's waste-in-place could be estimated in some cases.

Step 3: Determine Operational Status.

Landfills closed prior to January 1, 1993 were classified as other.

Landfills with reported status as operational or closed after 1993 and that had more than 1,000,000 tons of municipal solid waste in place were considered candidate projects.

2.3 National Databases Used to Complete Profiles

In addition to data collected from state, regional, or local offices, data was drawn from several national data sources. These sources include:

- ❑ Government Advisory Associates (GAA, 1994) — provides information on current and planned LFG Energy Recovery Projects;
- ❑ Electric Power Research Institute (EPRI, 1992) — examines the potential to use fuel-cells at large landfills;
- ❑ SCS Engineers (SCS, 1994) — examines the potential for landfill energy recovery projects in the Northeast;
- ❑ Solid Waste Association of North America (SWANA, 1992) — lists all landfills in the U.S.;
- ❑ Solid Waste Technologies (SWT, 1994) –– reports on landfill gas-to-energy facilities throughout North America;
- ❑ Solid Waste Atlas (SWA, 1994) –– lists all solid waste landfills in the U.S., transfer stations, incinerators, and waste-to-energy facilities; and

- Landfill Gas Utilization--Survey of United States Projects (Thorneloe, 1997) — lists all planned, under construction, and operational landfill gas-to-energy projects as of 1997.

Exhibit 2-1 provides a detailed description of the types of information available from each data source. The data obtained from the national databases were used mainly to supplement or verify data received from state or local offices. One exception is the Government Advisory Associates (GAA, 1994) data, which provided information on current and planned landfill gas recovery projects. Because data on landfill gas recovery projects were difficult to obtain from the states, GAA data were used as the primary source of information on current and planned energy recovery projects.

Exhibit 2-1. Summary of National Databases

	GAA Methane Recovery from Landfill Yearbook	EPRI Survey of Landfill Gas Generation Potential; 2 MW Molten Carbonate Fuel Cell	SCS Implementation Guide for Landfill Gas Recovery Projects in the Northeast
Purpose of Report	Provides information on current and planned LFG energy recovery projects	Examines the potential to use fuel-cells at large landfills	Examines the potential for landfill energy recovery projects in the Northeast
Types of Landfills Discussed in the Report	MSW landfills that have current or planned energy recovery projects	Large MSW landfills with a minimum active life of 15 years and an average solid waste delivery rate of 72,000 tpy	MSW landfills with 20 or more acres and daily waste receipts of 100 tons per day or more
States Included in Report	All states	All states, but more detailed information provided for Minnesota and Wisconsin	Northeastern states
Types of Landfill Data Included in Report	Detailed information on more than 120 fully operational LFG energy recovery projects and over 90 in development, including general landfill data, landfill gas collection system, landfill gas processing/energy generation system, institutional arrangements, operating issues, and costs	Identifies 749 candidate landfills in all states, and provides: site name, location, waste flow, years remaining, maximum and ten year gas flows, and number of 2MW units. For Minnesota and Wisconsin, the above information includes year opened, contact name and phone, utility, and gas controls	Identifies 207 candidate landfills in the northeast, and provides: landfill site name, location, address, phone number, contact person, and ownership; landfill acreage; estimated in-place refuse; waste flow; estimated closure year; and landfill gas features
Methods and Sources Used for Data Collection	Listing of sites compiled through GAA's contacts in the public and private sector as well as a review of articles. A detailed questionnaire was administered by phone, in several cases the contact person provided supplementary written materials	Data gathered from Cambridge Environmental Group, GAA, and SWANA. Data on landfills in Minnesota and Wisconsin were obtained directly from state agencies and from landfill operators	Contacted solid waste regulatory agencies; reviewed Solid Waste Atlas, SWANA Directory, and SCS Project files; and incorporated EPRI data
Year When Landfill Data Were Collected	1994; Updated on a yearly basis	1992	1994
How Data from National Report are Used in EPA Profiles Report	Data used to supplement missing information	Data used to supplement missing information	Data used to supplement missing information

Exhibit 2-1. Summary of National Databases (cont'd)

	EPA-ORD Landfill Gas Utilization- Survey	SWANA U.S. Landfill Directory	SWT Landfill Gas-to-Energy 1994-1995 Activity Report	SWA Directory and Atlas of Solid Waste Disposal Facilities
Purpose of Report	Lists information on all planned, under construction, and operational landfill gas-to-energy projects	Lists all landfills in the U.S.; goal of report not linked to energy recovery	Status report providing landfill gas-to-energy facilities throughout North America	Lists all landfills in the U.S., transfer stations, and incinerators and waste-to-energy facilities
Types of Landfills Discussed in the Report	New, existing and closed landfills throughout the U.S.	MSW landfills	214 landfill gas recovery facilities; 143 operational, 14 under construction, and 57 planned	MSW disposal facilities
States Included in Report	All states	All states with the exception of Montana	35 states with operating facilities, and under construction and planned facilities. Includes landfills in Canada	All states
Types of Landfill Data Included in Report	The database includes landfill gas utilization technologies, Operator/Developer information, project start dates, KW of energy produced, and type of collection systems	The Directory is comprised of over 4,300 facility names and addresses with most referencing the contact name and telephone number	Information includes the capital cost of each facility, the current gas generation of the landfill, mega watt capacity for projects producing electricity, and the identity of electricity or direct gas sales customers	Directory contains 4,500 public and private disposal facilities. Provides names and locations, with corresponding names, addresses, and phone numbers for both owners and operators, average daily intake, and the expected or permitted closure dates

Exhibit 2-1. Summary of National Databases (cont'd)

	EPA-ORD Landfill Gas Utilization- Survey	SWANA U.S. Landfill Directory	SWT Landfill Gas-to-Energy 1994-1995 Activity Report	SWA Directory and Atlas of Solid Waste Disposal Facilities
Methods and Sources Used for Data Collection	Information obtained from existing databases, LFGTE industry, magazine publications, government publications, and case studies	Directory information obtained by contacting each state using the "Directory of Solid Waste Management Program Officials"	Community personnel and owners of landfills and landfill gas-to-energy projects	Publisher's solid waste database, state agencies, trade associations, and facilities
Year When Landfill Data Was Collected	1997	1993; Pin Point Technologies now collects this data, updated daily	1994	1994
How Data from National Report are Used in EPA Profiles Report	Data used to supplement outdated information	Data used to supplement missing information	Data on operating facilities, under construction and planned facilities is used	Confirmation of owner or operator contact data

3. Landfill Profiles: Definition of Data Fields

This chapter describes the information contained in the landfill profiles. A sample profile is provided at the end of this section. Landfill profiles are available for current projects (which include both operational and under construction landfill gas-to-energy projects), candidate landfills (landfills that have a reported status of 'planned' or 'potential'; or landfills currently operating or closed after 1993 and have more than 1,000,000 waste-in-place), and those landfills with shutdown LFGTE projects. The information in the profile is grouped into five sections:

A. General Landfill Information
B. Landfill Gas Collection
C. Landfill Gas Utilization
D. Environmental Benefits of Utilization
E. Contact Information

Current Projects, Candidate Projects, and Shutdown landfill profiles are provided in the separate state-specific profiles document entitled *Landfill Gas-to-Energy Project Opportunities, Landfill Profiles for the State of [STATE]*. Landfills classified as Other and Unknown WIP are only identified in Exhibit 3 of the state-specific profiles document.

A detailed description of each entry on the landfill profile sheet is presented below. When no information was available for a value, the data field is reported as blank or zero. The accuracy of the data depends on the quality of the information contained in the source documents reviewed (further information on data collection activities and data interpretations is provided in Chapter 2).

3.1 A. General Landfill Information

The first section of each profile provides a brief overview of the landfill, including information on its physical location, owner, operating status, waste acceptance rate, and design capacity. This overview section also lists any alternate names for the landfill. Specific items included are:

- ❑ **Landfill Owner.** The landfill owner/owners names or company name.

- ❑ **Landfill Owner Type.** Type of landfill owner (e.g., municipal or private).

- ❑ **Alternative Landfill Name(s).** Any identified name for the landfill that is significantly different from the main landfill name. Many landfills have operated under different names at different times in their history.

- ❑ **City, County, State.** The physical location of the landfill site, including city, county, and state.

- ❑ **Year Open.** The year the landfill opened. Throughout the data collection process, for cases in which the open year was not available, the year the first (or oldest) permit was issued was used as the open year.

- **Year Closed.** The year the landfill stopped accepting waste (closed landfills), or is scheduled to stop accepting waste (i.e., for open landfills, the year landfill plans to close).

- **Annual Acceptance Rate (tons).** The amount of waste received and landfilled for a reported year, including all waste types, reported in short tons (tons). If only a daily acceptance rate is available, an annual acceptance rate is calculated by multiplying the daily acceptance rate by 52 weeks and the days open per week. When multi-year annual acceptance rate data are available, the most recent year's acceptance rate is presented in the profile.

- **Year Annual Acceptance Rate Reported.** The year corresponding to the annual acceptance rate.

- **Design Capacity (tons).** The total amount of waste that the landfill is designed to accept, reported in tons. This information is also called current permitted capacity. Values reported in cubic yards are converted to tons, by assuming a density of 1 ton/1.667 cubic yards.

- **Area Currently Landfilled (acres).** The number of acres that have been landfilled. Where possible, this has been made distinct from the area permitted or the property boundary.

- **Average Depth (feet).** The average depth of the landfilled waste, reported in feet. This value should exclude any buried soil cover and landfill cap material.

- **XXXX Waste-in-Place Year (tons).** WIP corresponding to the year xxxx. The data base stores a time series of WIP values. The WIP reported on the landfill profile is the value corresponding to the year for which the WIP is reported.

- **1998 Current Waste-in-Place (tons).** The total amount of waste that has been landfilled since the landfill opened. All waste types are included, and units other than tons are converted using landfill specific information where available, or by assuming a density of 1 ton/1.667 cubic yards. The following four calculations are used, in the order presented, to estimate WIP when variables are missing due to unreported raw data:

    1. For landfills where the estimated current year WIP is not known, it is estimated from the most recent available estimates of waste-in-place (WIP) and acceptance rate.[3]

[3] Profile sheet indicates year associated with WIP. For example: 1998 WIP is the WIP as of 1998.

Equation 1:

Current WIP (tons) =

Reported WIP[a] (tons) + (Annual Acceptance Rate (tons/yr) x (Current or Closed Year - Year WIP Reported [b]))

[a]Reported amount of waste-in-place.
[b]Year corresponding to reported WIP.

2. If no estimate of the reported WIP was available for any year, then the estimated current WIP is estimated from the Year Opened, and the Annual Acceptance Rate, as follows:

Equation 2:

Current WIP (tons)=

Annual Acceptance Rate (tons/yr) x (((Current or Closed Year) + 1) - Year Opened)

Equation 2 also applies to those landfills for which a reported WIP estimate is available, however, the year corresponding to the WIP is not available. In these cases, the 1998 WIP may be less than the reported WIP (without a corresponding year) indicated on the landfill profile as the 1998 WIP is based on the average annual acceptance rate. (When multi-year annual acceptance rates are available, the average value of the reported acceptance rates was used in the above equations.)

3. If acceptance rate data are not available, the latest reported WIP is used as the estimated current WIP (i.e., the WIP was not adjusted to account for the waste disposed of since the year of the WIP was reported).

4. If acceptance rate data and reported WIP are not available, the estimated current WIP is estimated from the landfilled acreage, the average depth, and an assumed MSW density 1 ton/1.667 cubic yards.

Equation 3:

Current WIP (tons) = Area Currently Landfilled x Average Depth x Density of Waste

or

Current WIP (tons) = Area (acres) x Depth (ft) x 1,613.33 (yd^3/acre-ft) x (1 ton/1.667 yd^3)

3.2 B. Landfill Gas Collection

This section presents information on current gas collection activities, including whether a gas collection system is in place, the current volume of landfill gas collected, and the estimated methane generation. Many landfills without gas utilization systems still collect landfill gas for safety reasons. For those landfills that are in the planning stages of developing a collection system, the data presented in this section represent the anticipated characteristics of the system. For landfills that have shut down their collection systems, the data reflect the characteristics of the collection system when it was operating.

❑ **Estimated Methane Generation (mmscf/d).** Methane (CH_4) is generated in landfills as the organic content of the waste decomposes. Estimated Methane Generation in million standard cubic feet per day (mmscf/d) is based on two equations adapted from U.S. EPA 1993b, *Opportunities to Reduce Anthropogenic Methane Emissions in the United States*. Equation 4a estimates annual methane for landfills with less than 907,200 tons of waste -in-place. Equation 4b estimates annual methane for landfills equal to or greater than 907,200 tons of Waste in Place. These equations were derived from statistical analyses of existing projects.[4]

This methodology is based on the assumption that waste has a 30-year methane generation life span. Therefore, the Waste-in-Place value used to estimate emissions excludes waste that was accepted more than 30 years before the current year. This waste value is referred to as WIP_m. For further information refer to the EPA's LMOP's 1997 *Energy Project Landfill Gas Utilization Software, E-PLUS User's Manual, Version 1.0*; pp. 40-41.

Equation 4a:

(WIP<907,200 tons)
CH_4 generation (mmcf/d) = $0.05085 \times (6.95 \times 10^{-6} \times WIP_m \text{ (tons)})$

Equation 4b:

(WIP≥907,200 tons)
CH_4 generation (mmcf/d) = $0.05085 \times [8.22 + (5.03 \times 10^{-6} \times WIP_m \text{ (tons)})]$

If the landfill began accepting waste less than 30-years from the publication date of the landfill profiles, then WIP_m is considered to be the same as the WIP calculated using the method described in Section 3.1. If the landfill began accepting waste over 30 years ago, then WIP_m is calculated by estimating the total quantity of waste that was placed in the landfill within the last 30 years.[5] For these landfills WIP_m is calculated as follows:

---

[4] These equations are generally applicable to landfills in non-arid regions (i.e., more than 25 inches of precipitation annually). Consequently, methane generation will be overestimated for landfills in arid regions.

[5] If the open year is missing, then the open year is defaulted to 1900. This assumption reduces the likelihood of overestimating the methane generation for those landfills for which limited data are available (in particular for older landfills that have limited methane generation potential).

Equation 4c:

WIP_m (tons) =

(WIP (tons)/(current year-open year)) x (number of years the landfill has been open in the past 30 years)

One limitation of this methane generation model is its use of national averages to estimate individual landfills' gas generation rates. While such a model may provide a useful indication of potential gas flow, site specific factors are not included, such as percent MSW, age, moisture content, temperature, pH, and density of waste. This may diminish the accuracy of the predicted gas flow. Since such models can generate estimates with potentially large uncertainties, site monitoring is extremely important in order to verify gas flows.

- **Collection System Status.** Indicates whether a LFG collection system is operational, planned, shutdown, under construction, none, or NA (i.e., unknown).

- **Current LFG Collected (mmscf/d).** The reported volume of landfill gas flowing through the collection system, in million standard cubic feet per day (mmscf/d).

- **Collection and Treatment System Required under NSPS/EG.** As reported by state agencies, and landfill owners or operator, indicates whether a collection and treatment system is required under NSPS/EG. (A 'No' indicates either not required or unknown).

3.3 C. Landfill Gas Utilization

This section presents information on the status of the landfill's landfill-gas-to-energy projects. First, the utilization status, electric utility and natural gas providers, and existing energy purchases are presented. Second, estimates are provided for the potential capacity for electricity generation projects (in MW) and direct use projects (in mmBtu/hr). Available data on current and planned capacity are also provided.

- **Utilization System Status.** The status of gas utilization activities at the landfill. Standard entries are: operational, construction, planned, shutdown, potential, low interest or N.A. (Not Available).

- **Utilization System Type.** Type of methane gas usage (e.g., IC gas, gas turbine, fuel cell, boiler, high Btu, medium Btu, leachate evaporation, and vehicle fuel).

- **Utilization Start Year.** The year the landfill began collecting and treating and utilizing their landfill gas.

- **Electric Utility Provider.** Current electric utility provider(s) at the landfill.

- **Natural Gas Utility Provider.** Current natural gas utility provider(s) at the landfill.

- **Energy Purchaser.** The end user or purchaser utilizing the energy from landfill gas.

- **Estimated Potential Capacity.** These values represent the total installed potential capacity that could be supported by the landfill site, assuming the landfill gas is collected and used for either 1) electricity generation project, or 2) a direct use project (.e., boiler fuel).[6]

> Equation 5:
>
> Estimated Potential Capacity for Electricity Generation Project (MW) =
>
> Estimated Methane Generation (mmscf/day)[7] x Gas Collection Efficiency (0.75)[a] x 1 day/24 hrs x 1,000 Btu/scf x 10^6 scf/mmscf x 1 kWh/10,000[b] Btu x 1 MW/1,000 kW
>
> [a]A default value of 0.75 is assumed for the Gas Collection Efficiency.
> [b]A default value of 10,000 Btu/kWh is assumed for the IC engine heat rate.

> Equation 6:
>
> Estimated Potential Capacity for Direct Use Project (mmBtu/hr) =
>
> Estimated Methane Generation (mmscf/day) x Gas Collection Efficiency (0.75) x mmBtu/1,000,000 Btu x 1,000 Btu/scf x 1,000,000 scf/mmscf x 1 day/24 hours

- **Current Capacity.** These values are the reported installed capacity for existing electricity generation or direct use projects. For direct use projects, the capacity has been converted from the reported units of mmBtu per year to mmBtu/hr using a conversion factor of 1 year/ 8,760 hours.

> Equation 7:
>
> Current Capacity for Direct Use Project (mmBtu/hr) =
>
> Current Gas Capacity (mmBtu/yr) x 1 yr/8760 hours

- **Planned Capacity.** If a landfill gas project is in the planning stages or under construction, the planned capacity is presented here. These values are typically obtained from GAA (1994), SWT (1994), Thorneloe (1997), project developers, and landfill owners and operators. For direct use projects, the capacity has been converted from the reported units of mmBtu per year to mmBtu/hr using a conversion factor of 1 year/ 8,760 hours.

---

[6] Although other users exist for landfill gas, these types of projects are the most common applications and, therefore, these types of projects have been selected for the purpose of the landfill profiles.

[7] The volume of landfill gas is approximately double the estimated volume of methane generation.

Equation 8:

Planned Capacity for Direct Use Project (mmBtu/hr) =

Planned Gas Capacity (mmBtu/yr) x 1 yr/8760 hours

- **Utilities in County.** The utilities in the county in which the landfill is located are listed.

3.4 D. Environmental Benefits of Utilization

This section presents data on both the potential and current environmental benefits of landfill gas collection and utilization. Based on the estimates of potential methane generation and capacity for electricity generation and direct use projects, estimates for emissions avoided by fossil fuel displacement are presented.

- **Potential Methane Reduction (tons/yr).** This value differs from Estimated Methane Generation because it incorporates the collection efficiency. For landfills where an actual collection efficiency is not available, a default value collection efficiency of 75 percent is used. The efficiency will be less than 100 percent due to a number of factors including: poor well placement and air infiltration through landfill covers, the well-head, and lateral pipe connections. Collection efficiency can range from 5 to 95 percent based on landfill age and design (see EPA's *E-Plus User's Manual*, for further information).

Equation 9:

Potential Methane Reduction (tons/yr) =

Estimated Methane Generation (mmscf/day) x
Collection Efficiency (0.75) x 365 days/yr x 21.12 tons/mmscf

The estimate of Potential Methane Reduction presented here is likely to be an overestimate because, in the absence of the gas recovery system, a portion of the methane produced in the landfill would be oxidized as it migrates out of the landfill. The portion of the methane that is oxidized is not emitted to the atmosphere, and therefore does not contribute to landfill methane emissions. Withdrawing the gas with a collection system prevents this oxidation step, so that more methane is recovered than would otherwise have been emitted. The extent of oxidation that will occur can vary greatly depending on local conditions, and an estimated is not incorporated here.

- **Current Methane Reduction (tons/yr).** The current volume of reported landfill gas collected converted to tons per year.

Equation 10:

Current Methane Reduction (tons/yr) =

Current LFG Collected (mmscf/day) x Percent Methane[a] x 365 days/yr x (21.12 tons/mmscf)[b]

[a]Assume default value of 50 percent methane in LFG.
[b] Assume the density of methane at degrees Celsius and 1 atmosphere is 21.12 tons/mmscf.

CO_2 Equivalent of Potential Methane Reductions (tons/yr). The magnitude of the methane emissions that could potentially be reduced through increased landfill gas collection, expressed in tons of carbon dioxide equivalent per year. The Potential Methane Reduction is converted to tons of CO_2 equivalent per year using a Global Warming Potential of methane equal to 21.[8]

Equation 11:

CO_2 Equivalent of Potential CH_4 Emission Reductions (tons/yr) =

Potential Methane Reduction (tons/yr) x 21 CO_2/CH_4

- **CO_2 Equivalent of Current Methane Reduction (tons/yr).** The magnitude of the current methane reductions achieved through current landfill gas collection, expressed in thousand tons of carbon dioxide equivalent per year.

Equation 12:

CO_2 Equivalent of Current Methane Reduction (tons/yr) =

Current Methane Reduction (tons/yr) x 21 CO_2 / CH_4

- **Emissions Avoided By Fossil Fuel Displacement (tons/yr).** Landfill gas utilization projects can result in avoided emissions not only of methane, but also of CO_2 and SO_2. The collection of landfill gas and its subsequent use as a fuel for electricity generation and direct use projects will displace the fuse of fossil fuel and thereby reduce net emissions. The magnitude of the emissions avoided in this manner depends on the emission characteristics of the displaced fuel. These emissions are highly dependent on the exact type of fuel (especially the sulfur content of coal), the equipment type, and emission control technologies in place. While the emission characteristics for

[8] The Global Warming Potential (GWP) is an expression of the radiative forcing of one mass unit of methane relative to one mass unit of carbon dioxide. Thus, one gram of methane has 21 times the radiative forcing of one gram of carbon dioxide over a 100 year time frame. For additional information see IPCC 1995.

individual projects should be estimated using regional or local values, national averages have been used for illustrative purposes in the profiles.

Presented below are the approaches for estimating emissions avoided by substituting landfill gas as a fuel source in electricity generation and direct use projects. These estimates exclude the additional avoided emissions caused by reducing emissions from flares at capped landfills or uncontrolled emissions at uncapped landfills.

Electricity Generation Project

To estimate the avoided CO_2 and SO_2 emissions from substitution of landfill gas for other fossil fuels for electricity generation projects, the potential energy displaced is multiplied by an emissions factor. Exhibit 3-1 presents the emissions factors for three types of fossil fuels. The estimated avoided emissions are based on the assumption that the displaced fuel is *all* coal, oil, or natural gas rather than a combination of these fuel types.[9] A more realistic and accurate approach to quantifying avoided emissions is to estimate the fuel mix being 'backed-off' of the electric grid as a result of the project. However, because each region has its own particular resource mix, this single-fuel displacement assumption is being used to provide an order-of-magnitude estimate of avoided emissions.

Exhibit 3-1. Offset Emissions for Displaced Fuel Used for Electricity Generation Project[a]

Type of Displaced Fuel	CO_2 [b] (lbs/mmBtu)	SO_2 [c] (lbs/kWh)
Coal	212	0.0134
Fuel Oil	174	0.0112
Natural Gas	117	0.000007

[a]Offset emissions factors are national averages (i.e., total national emissions/total national generation).
[b]Source: U.S. Department of Energy, Energy Information Administration, *Instructions for Form EIA-1605 (1998), Voluntary Reporting of Greenhouse Gases, OMB No. 1905-0194*, p. 47.
[c]Source: U.S. Department of Energy, Energy Information Administration, *Electric Power Annual 1997,* Volume I, Table 10, and Volume II, Tables 25, 61, and 62, DOE/EIA-0348(97).

[9] The emissions avoided are not additive across fuel types because the estimates are based on the assumption that all of the specific fossil fuel is being displaced with landfill gas (rather than a fuel mix being displaced with landfill gas).

Equation 13:

Potential Energy Displaced (Electricity) (kWh/yr) =

Estimated Potential Capacity for Electricity Generation Project (MW) x
8760 hrs/yr x IC Engine Availability Factor (0.85) x 1,000 kW/MW

Equation 14:

Avoided CO_2 Emissions From Substituting LFG for Coal in
Electricity Generation Project (tons/yr) =

Potential Energy Displaced (Electricity) (kWh/yr) x 10,000 Btu/1 kWh x 212 lbs/mmBtu x
1 mmBtu/1,000,000 Btu x 1 ton/2,000 lbs

Equation 15:

Avoided SO_2 Emissions From Substituting LFG for Coal in
Electricity Generation Project (tons/yr) =

Potential Energy Displaced (Electricity) (kWh/yr) x 0.0134 lbs/kWh x
1 ton/2,000 lbs

Equation 16:

Avoided CO_2 Emissions From Substituting LFG for Fuel Oil in
Electricity Generation Project (tons/yr) =

Potential Energy Displaced (Electricity) (kWh/yr) x 10,000 Btu/1 kWh x
174 lbs/mmBtu x 1 mmBtu/1,000,000 Btu x 1 ton/2,000 lbs

Equation 17:

Avoided SO_2 Emissions From Substituting LFG for Fuel Oil in
Electricity Generation Project (tons/yr) =

Potential Energy Displaced (Electricity) (kWh/yr) x 0.0112 lbs/kWh x 1 ton/2,000 lbs

---

Equation 18:

Avoided CO_2 Emissions From Substituting LFG for Natural Gas in
Electricity Generation Project (tons/yr) =

Potential Energy Displaced (Electricity) (kWh/yr) x 10,000 Btu/1 kWh x
117 lbs/mmBtu x 1 mmBtu/1,000,000 Btu x 1 ton/2,000 lbs

Equation 19:

Avoided SO_2 Emissions From Substituting LFG for Natural Gas in
Electricity Generation Project (tons/yr) =

Potential Energy Displaced (Electricity) (kWh/yr) x 0.000007 lbs/kWh x

Direct Use Project

To estimate the emissions of CO_2 and SO_2 avoided by substituting landfill gas for other fossil fuels in direct use projects, the potential energy displaced is multiplied by an emissions factor. Exhibit 3-2 presents the emissions factors for three types of fossil fuels. The derived estimates are based on the assumption that the displaced fuel is all coal, oil, or natural gas rather than a combination of these fuel types. Given that direct use projects generally utilize one fuel type, this approach is appropriate, however the emissions avoided are not additive across fuel types.

Exhibit 3-2. Offset Emissions for Displaced Fuel Used for Direct Use Project[a]

Type of Displaced Fuel	CO_2 [b] (lbs/mmBtu)	SO_2 [c] (lbs/mmBtu)
Coal	212	1.929
Fuel Oil	174	1.014
Natural Gas	117	0.001

[a]Offset emissions factors are national averages (i.e., total national emissions/total national generation).
[b]Source: U.S. Department of Energy, Energy Information Administration, *Instructions for Form EIA-1605 (1998), Voluntary Reporting of Greenhouse Gases*, OMB No. 1905-0194, p. 47.
[c]Source: ICF Resources, Industrial, Commercial, and Institutional (ICI) Boiler Database, 1998.

Equation 20:

Potential Energy Displaced (Fuel) (mmBtu/yr) =

Estimated Methane Generation (mmscf/day) x Gas Collection Efficiency (0.75) x Hours of Operation (0.60) x 1,000 Btu/scf x mmBtu/1,000,000 Btu x 1,000,000 scf/mmscf x 365 days/yr

---

Equation 21:

Avoided CO_2 Emissions From Substituting LFG for Coal in Direct Use Project (tons/yr) =

Energy Displaced (fuel) (mmBtu/yr) x 212 lbs/mmBtu x 1 ton/2,000 lbs

---

Equation 22:

Avoided SO_2 Emissions From Substituting LFG for Coal in Direct Use Project (tons/yr) =

Energy Displaced (fuel) (mmBtu/yr) x 1.929 lbs/mmBtu x 1 ton/2,000 lbs

Equation 23:

Avoided CO_2 Emissions From Substituting LFG for Fuel Oil in Direct Use Project (tons/yr) =

Energy Displaced (fuel) (mmBtu/yr) x 174 lbs/mmBtu x 1 ton/2,000 lbs

---

Equation 24:

Avoided SO_2 Emissions From Substituting LFG for Fuel Oil in Direct Use Project (tons/yr) =

Energy Displaced (fuel) (mmBtu/yr) x 1.014 lbs/mmBtu x 1 ton/2,000 lbs

---

Equation 25:

Avoided CO_2 Emissions From Substituting LFG for Natural Gas in Direct Use Project (tons/yr) =

Energy Displaced (fuel) (mmBtu/yr) x 117 lbs/mmBtu x 1 ton/2,000 lbs

---

Equation 26:

Avoided SO_2 Emissions From Substituting LFG for Natural Gas in Direct Use Project (tons/yr) =

Energy Displaced (fuel) (mmBtu/yr) x 0.001 lbs/mmBtu x 1 ton/2,000 lbs

3.5 E. Contact Information

This section presents, where available and applicable, contact information on the landfill owner and landfill operator, including, primary contact name, mailing address, city, state, zip, phone, and fax are included.

3.6 Summary of Default Values

This table lists default values used in calculations where critical raw data are not available.

Default Element	Default Value
Days Landfill Open	5.5 days per week
Gas Collection Efficiency[a]	0.75
Methane in Landfill Gas	50 %
Density of Landfilled Waste	1 ton/ 1.667 cubic yards
IC Engine Heat Rate	10,000 BTU/1 kWh
Density of Methane at 15 degrees Celsius and 1 atmosphere	21.12 tons/mmscf
Energy Content of Methane	1,000 Btu/scf
Boiler Availability Factor	.85
IC Engine Availability Factor	0.85

[a]This value accounts for LFG system down time and electricity used to operate the gas recovery engine equipment.

4. References

GAA,1994. *1994-5 Methane Recovery from Landfill Yearbook*, Governmental Advisory Associates.

EPRI, 1992. *Survey of landfill Gas Generation Potential: 2 MW Molten Carbonate Fuel Cell*, Electric Power Research Institute.

Federal Register, 1998. June 16, 1998 (Volume 63, Number 115) Rules and Regulations, page 32743-32753.

IPCC, 1995. *Climate Change 1995: The Science of Climate Change*. Intergovernmental Panel on Climate Change.

Landfill Control Technologies, 1994. "Landfill Gas System Engineering Design Seminar."

Maxwell, 1990. Will Gas-to-Energy Work at Your Landfill? Solid Waste & Power.

Michels, 1997. Solid Waste Technologies, July 18, 1997.

NSWMA, 1985. *Basic Data: Solid Waste Amounts, Composition and Management Systems*, National Solid Waste Management Association, Technical bulletin #85-6, October 1, 1985.

SCS, 1994. *Implementation Guide for Landfill Gas Recovery Projects in the Northeast: Draft Final Report*, SCS Engineers.

Solid Waste Technologies, 1994. *Landfill Gas-to-Energy 1994-1995 Activity Report*, HCI Publications.

SWANA, 1992. *U.S. Landfill Directory*, Solid Waste Association of North America.

Thorneloe, Cosulich, Pacey and Roqueta, 1997. *Landfill Gas Utilization- Survey of United States Projects.* Presented at the Solid Waste Association of North America's Twentieth Annual International Landfill Gas Symposium, Monterey, California, March 25-27, 1997. Publish in Conference Proceedings. EPA-ORD 1997. Environmental Protection Agency office of Research and Development.

Thorneloe, 1992. *Landfill Gas Recovery/Utilization - Options and Economics*. Presented at the Sixteenth Annual Conference by the Institute of Gas Technology on Energy from Biomass and Wastes, Orlando, Florida, March 15, 1992.

Thorneloe and Pacey, 1994a. *Database of North American Landfill Gas-to-Energy Projects*. Presented at the 17th Annual International Landfill Gas Symposium by the Solid Waste Association of North America, Long Beach, California, March 22-24, 1994. Published in Conference Proceedings.

Thorneloe and Pacey, 1994b. *Landfill Gas Utilization - Technical and Non-Technical Considerations*. Presented at the 17th Annual International Landfill Gas Symposium by the Solid Waste Association of North America, Long Beach, California, March 22-24, 1994. Published in Conference Proceedings.

Thorneloe and Pacey, 1995. *Database of North American Landfill Gas-to-Energy Projects*. Presented at the 18th Annual International Landfill Gas Symposium by the Solid Waste Association of North America, New Orleans, Louisiana, March 27-30, 1995. Published in Conference Proceedings.

U.S. Department of Energy, Energy Information Administration (1998), *Instructions for Form EIA-1605 (1998), Voluntary Reporting of Greenhouse Gases, OMB No. 1905-0194*.

U.S. Department of Energy, Energy Information Administration (1997), *Electric Power Annual 1997*, Volume I and Volume II, DOE/EIA-0348(97).

U.S. EPA,1993. *Opportunities to Reduce Anthropogenic Methane Emissions in the United States: Report to Congress*, United States Environmental Protection Agency. EPA 430-R-93-012.

U.S. EPA, 1994. *Turning a Liability into an Asset: A Landfill Gas-to-Energy Handbook for Landfill Owners and Operators*, United States Environmental Protection Agency.

U.S. EPA, 1998. *Helping Landfill Owners Achieve Effective, Low-Cost Compliance with Federal Landfill Gas Regulations*. United States Environmental Protection Agency.

U.S. EPA, 1993a. *Anthropogenic Methane Emissions in the United States: Estimates for 1990, Report to Congress*, United States Environmental Protection Agency. EPA 430-R-93-003.

Utility Data Institute, 1995. U.S. Electric Utility Demographics from the Electrical World Directory. UDI, Washington, DC.

Landfill Name	*Landfill Category:*

A. GENERAL LANDFILL INFORMATION

Landfill Owner:
Landfill Owner Type:
Alternative Landfill Name:
City:
County:
State:
Year Open:
Year Closed:

Annual Acceptance Rate (tons):
Year Annual Acceptance Rate Reported:
Design Capacity (tons):
Acres Currently Landfilled (acres):
Average Depth (feet):
Waste-in-Place (tons):
1998 Waste-in-Place (tons):

B. LANDFILL GAS COLLECTION

Estimated Methane Generation (mmscf/d):
LFG Collection System Status:
Current LFG Collected (mmscf/d):
Collection and Treatment System Required Under NSPS/EG:

C. LANDFILL GAS UTILIZATION

Current Utilization:
- Utilization System Status:
- Utilization System Type:
- Utilization System Start Year:
- Electric Utility Provider(s):
- Natural Gas Provider(s):
- Energy Purchaser(s):

Capacity:	Electricity Generation Project (MW) OR	Direct Use Project (mmBtu/hr)
Estimated Potential Capacity: Current Capacity: Planned Capacity:		

Utilities in County:

D. ENVIRONMENTAL BENEFITS OF UTILIZATION

	Potential		Current	
Methane Reduction (tons/yr): *CO2 Equivalent of CH4 Reduction (tons/yr):*				
Emissions Avoided by Fossil Fuel Displacement:	*Electricity Generation Project*		*Direct Use Project*	
	CO2 (tons/yr)	*SO2 (tons/yr)*	*CO2 (tons/yr)*	*SO2 (tons/yr)*
Coal:				
Fuel Oil:				
Natural Gas:				

E. CONTACT INFORMATION

	Landfill Owner	Landfill Operator
Contact Name:		
Mailing Address:		
Phone Number:		
Fax Number:		

* *Itallicized indicates values estimated by EPA.*