Industrial Use of Landfill Gas:
Resource Packet

Industrial energy challenges can be significant, and the opportunity to harness a variety of choices with commercially proven technologies can make a valuable difference for industrial facilities. The direct-use of landfill gas (LFG) by industrial facilities represents just such an opportunity, and the Global Methane Initiative (GMI) can assist with the evaluation and development of a LFG direct-use project at your industrial facility.

The term "direct-use" is used to describe projects that involve the use of LFG as an energy source for industrial applications. Direct-use of LFG has been successfully demonstrated in common industrial applications such as boilers, dryers, furnaces, kilns, process heaters, and radiant heaters. Industries from food and beverage production and automobile manufacturing to brick, concrete and asphalt production have all benefitted from utilizing LFG as a fuel source for their energy needs. Using LFG has helped over 100 companies stabilize their fuel costs, reduce their environmental impact, and improve their image as a leader in sustainability within their communities and industries.

What is the Purpose of this Resource Packet?

If you have interest in using LFG for an industrial application, this resource packet is intended to help you begin the screening process to identify opportunities for a successful direct-use project. It provides you with background information on how direct-use projects historically have been developed, what information is needed to begin evaluation of a direct-use project, and general considerations related to the development of a direct-use project. Given that the vast majority of landfill gas energy (LFGE) projects are electrical generation projects and that direct-use applications vary greatly, this packet will give you the additional background needed to understand how these projects work and what the relevant points of consideration are. For a direct-use project to be successful there should be good compatibility between the solid waste disposal (SWD) site and the industrial facility with respect to the energy potential of the SWD site, the energy utilization profile of the industrial facility, and the physical proximity to each other.

What is Included in this Resource Packet?

This resource packet includes several tools to assist you in a preliminary evaluation of a direct-use project. There are two fact sheets that provide a general description of direct-use projects, what technical and economic considerations should be addressed during such an evaluation, and a detailed description of how the most common type of direct-use application, boilers, can be adapted to use LFG. There are also two data collection forms that outline the information needed to evaluate both the energy potential from an SWD site and the energy utilization profile of an industrial facility.

The evaluation tools contained in this packet are listed below with a description of their content and use:

- **Direct-Use of Landfill Gas for Energy.** This fact sheet provides a brief introduction to direct-use project types, the economic and environmental benefits of these projects, and considerations that should be addressed during the development of a direct-use project. You will have a general understanding of direct-use projects after reading this fact sheet.
- **Adapting Boilers to Utilize Landfill Gas.** This fact sheet discusses the technical and engineering issues associated with using LFG in boilers originally designed to burn other fuels. Since the most common application of LFG at an industrial facility is boilers, this fact sheet will help you understand what type of modifications are required to utilize LFG in a boiler. Although it is focused on boilers, many of the modifications required to allow a boiler to utilize LFG also pertain to other equipment considered for LFG utilization.
- **Industrial Facility Data Collection Form.** Outlines the basic information needed to begin an evaluation of an industrial facility for a direct-use project by understanding its energy utilization profile. This data collection form is intended as a general guide for preliminary evaluation and should not be assumed to capture all important aspects critical to a successful direct-use project.
- **Solid Waste Disposal Site Data Collection Form.** Outlines the basic information needed to evaluate an SWD for its energy potential and suitability for a direct-use project.
- **International Unit Conversion Table:** Units of measurement for SWD sites and energy projects can vary throughout the world, and this table will help translate units common to LFGE projects.

The material in this packet can help you conduct a preliminary evaluation of a direct-use project. Successfully capitalizing on the value of these opportunities requires careful evaluation, and GMI can provide assistance with all the steps of the evaluation process. If you have further questions, please contact GMI at www.globalmethane.org.

Direct-Use of Landfill Gas for Energy:

A Potential Alternative to Electricity Generation

The direct-use of landfill gas (LFG) is a way in which many industrial facilities have realized significant fuel cost savings and improved their environmental impact. The term "direct-use" is used to describe projects that involve the use of LFG as an energy source for boilers, furnaces, heaters, kilns, and other types of process operations. Industrial facilities from food and beverage production to automobile manufacturing to brick and cement production have all benefitted from utilizing LFG as a fuel source for their energy needs.

Direct-Use LFG Project with Urban Forest Recyclers
Newton County Landfill, IN

In the U.S. alone, using LFG has helped over 100 industrial facilities to stabilize their fuel costs, reduce their environmental impact, and improve their image as a leader in sustainability within their community. Not only does LFG utilization benefit individual industrial facilities, it also has a positive impact on the entire community by increasing economic development and fostering creativity and innovation. Direct-use of LFG at industrial facilities is a well-established option for LFG utilization. Typically, LFG offsets the use of fossil fuels such as natural gas, oil, and coal, resulting in fuel cost savings and reduced greenhouse gas emissions. LFG is widely considered to be a renewable energy resource, and as such, direct-use projects can be an integral part of an industrial facility's environmental sustainability portfolio.

This document provides insight on direct-use project types, the economic and environmental benefits of these projects, and considerations that should be addressed during the development of a project. Information on how the Global Methane Initiative (GMI) can assist with the development of direct-use projects is also provided.

Landfill Gas Basics

LFG is the natural byproduct of the decomposition of organic material in solid waste disposal (SWD) sites under anaerobic conditions. The composition of LFG is roughly 50 percent methane, nearly 50 percent carbon dioxide, less than one percent of trace organic compounds, and varying levels of nitrogen and oxygen. The most common method for collecting LFG involves drilling vertical wells into the waste mass and connecting these wells to a system of piping that transports LFG to a combustion device through the use of a blower or vacuum induction system. In some cases, horizontal wells are laid in trenches in the waste while the SWD site is still accepting waste.

After collection, the LFG can be flared or used as a renewable energy source via the combustion of the methane contained in the LFG. If LFG is used directly in an industrial facility, some level of treatment may be required to remove excess moisture, particulates, and other impurities. The type and extent of treatment will depend upon the amount of contaminants in the raw LFG and the subsequent specifications required by the combustion device at the industrial facility.

Project Types

LFG can be utilized as a renewable energy resource in many different types of equipment. Common applications include boilers, dryers, furnaces, greenhouses, kilns, process heaters, and radiant heaters. The direct-use of LFG at industrial facilities has been demonstrated for over 30 years in the U.S., with the first direct-use project beginning operation in 1979.

Among the various direct-use applications, the use of LFG in boilers is the most common project application. In the U.S. alone, over 70 boilers have been modified to burn LFG either as the primary fuel or as a supplemental fuel. Boiler size is not an issue for these projects, as GMI has observed the use of LFG in boilers ranging from 0.6 megawatt-thermal (MWth) to 44 MWth of heat input capacity. For more information on LFG use in boilers, see www.epa.gov/lmop/documents/pdfs/boilers.pdf.

Benefits of Direct-Use Projects.

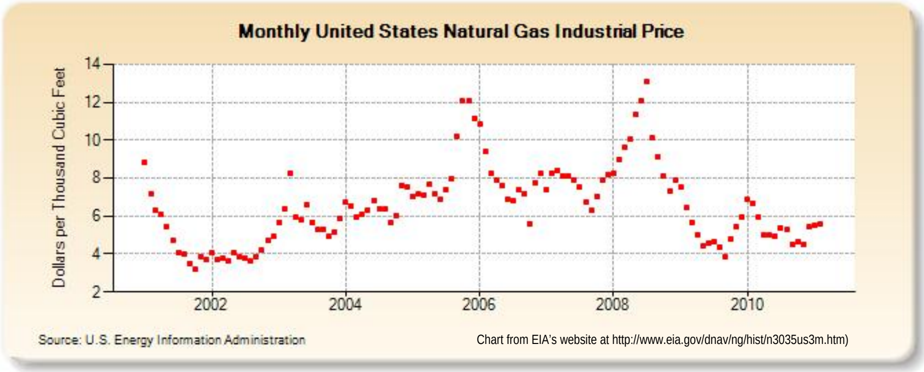
- Stabilizes fuel cost
- Promotes economic development
- Encourages community improvement and education
- Enhances environmental protection
- Generates positive press
- Increases project efficiency
- Does not require LFG to be upgraded to natural gas quality

Project Benefits

In the U.S., the percentage of direct-use projects among all beneficial LFG projects has grown significantly during the last several years. This growth has occurred despite an absence of incentive programs encouraging the development of these projects. Given the lack of incentives, the increase of direct-use projects suggests other factors are driving development. The following section summarizes the many benefits of direct-use projects that are driving more industrial facilities to consider LFG as a fuel source.

Stabilizes Fuel Costs: Utilizing LFG to offset the use of natural gas, coal, or fuel oil can help reduce and stabilize fuel costs. This is especially important in the industrial sector where energy can represent a significant portion of operating costs. Fossil fuel prices and even prices for other renewable energy sources often change quickly and drastically as the result of: (1) climate events such as hurricanes, droughts, and storms; (2) seasonal fluctuations in demand (e.g., extreme cold and heat); or (3) supply shocks or interruptions (e.g., international events or catastrophic disasters). As an example, the chart below from the U.S. Energy Information Administration shows the historical volatile/erratic pattern of natural gas pricing in the United States.

LFG prices are not as adversely impacted by these events, which gives industrial facilities the surety that their energy prices will remain relatively stable. Although LFG prices are often indexed to that of natural gas in direct-use contractual arrangements, the actual costs to collect and deliver LFG to an industry fluctuate little on their own accord. Even indexed LFG sales prices typically include a maximum and minimum price limitation. In some contract structures, fixed pricing is used in conjunction with an annual price escalation.



Promotes Economic Development: Direct-use projects can have a significant impact on job and revenue creation in the communities in which they are located. These projects create jobs associated with their design, construction, and operation. These positions often require highly skilled and technical staff and are filled by the local workforce and contractors. If the SWD site is owned by a municipality, direct-use LFG projects can also create additional revenue for local governments through the sale of LFG. Additional revenue also may be realized if emission reduction credits can be sold. For the above reasons, many industrial facilities looking to improve their environmental image are considering LFG as a renewable, reliable, and low cost fuel source for their operations and facilities. In some cases, the manufacturing facilities have even been sited and constructed adjacent to SWD sites for the sole purpose of using LFG.

Encourages Community Improvement and Education: Direct-use projects provide communities with a unique opportunity to establish and expand community programs. This is not only done through the revenue generated from the project, but also because the LFG project itself can serve as the starting point for an innovative community program. In Jackson County, North Carolina (U.S.), the County developed a Green Energy Park around their closed SWD site. This project created about 20 new jobs and established a community program for the arts whereby LFG is used to fire glassblowing studios and blacksmithing forges and to heat greenhouses. The greenhouses are used by florists to grow flowers to sell within the community and by the County to grow their own plants for use in landscaping projects. LFG projects also serve as a very important tool to educate community members on the need to use renewable energy and take steps to reduce greenhouse gas emissions. Hundreds of communities across the world showcase their use of LFG to school groups, civic organizations, and community leaders interested in building sustainable communities.

Direct-Use Project with MARS Snackfoods, City of Waco Landfill, TX

Enhances Environmental Protection: Direct-use of LFG benefits the environment in two significant ways. First, collection and utilization of LFG prevents the release of methane emissions into the atmosphere. This is important because methane is over 20 times more effective in trapping heat near the earth's surface than carbon dioxide. The direct-use of LFG also benefits the environment by offsetting the need to burn fossil fuels such as coal, oil, and natural gas. The mining, processing, and burning of these fossil fuels creates a significant amount of air pollution. By using LFG as a fuel source in boilers and furnaces instead of fossil fuels, it prevents the air pollution that would otherwise result from the use of these fossil fuels.

Generates Positive Press: Industries, municipalities, and other stakeholders are interested in utilizing LFG as a fuel source because it helps promote a green, renewable, and sustainable image and can be used to generate positive coverage in the news media. Customers and the public tend to support companies that are taking action to minimize their impact on the environment. Utilization of LFG helps industrial facilities reduce their greenhouse gas emissions and minimize their carbon footprint. Many industrial facilities also have established corporate sustainability goals that make minimizing their impact on the environment an integral part of how they do business. These goals often require the use of renewable resources to meet a portion of their energy needs. Public support for companies that adopt sustainability goals has led many major global industries to utilize LFG as an energy resource. Similarly, utilizing LFG can help many industrial facilities obtain green or sustainable certifications.

Increases Project Efficiency: Direct-use of LFG for heating or steam production is more efficient in comparison to the generation of electricity from LFG. A typical boiler project uses between 80 and 90 percent of the energy content of LFG. The remainder is lost as waste heat from the boiler. This compares to electricity generation using LFG where only about 30 percent of the energy value of LFG is converted into electricity, with about 70 percent being lost as waste heat.

Direct-Use project with POET, Sioux Falls Landfill, SD

Project Considerations

Many considerations must be weighed in order to determine whether or not a direct-use LFG project will be successful. For the industrial facility using LFG, the main considerations would be whether the conversion to LFG makes economic sense or meets a specific sustainability goal. The primary factors in such an economic evaluation include: the amount of LFG that could be collected from the SWD site; the capital costs needed to modify industrial equipment to burn LFG; the capital and operating costs needed to transport LFG to the industrial facility; and fuel use and price profiles for the industrial facility.

Estimating Landfill Gas Collection: A critical component of LFG project planning is the estimation of LFG collection potential, or the amount of LFG generated in the SWD site that can realistically be collected. Project financial models are based on LFG collection estimates. The amount of LFG that can be collected is a function of several site-specific factors; therefore, it is important to observe and analyze SWD site operations to obtain accurate data. SWD site characteristics to monitor include: the presence or absence of cover materials and cover material types; the size of the working face; waste types and quantities received; the extent of the LFG collection system; the age of the waste in place; and the presence of other environmental controls such as bottom liner systems. The SWD Site Data Collection Form developed by GMI provides a helpful outline of information needed to evaluate an SWD site for project feasibility (see http://www.globalmethane.org/tools-resources/tools.aspx#three).

This site-specific information is used to estimate the amount of LFG that will be available over time to fuel a direct-use project. GMI has developed a number of country-specific models for developing such estimates that use parameters tailored to climate conditions and waste types of individual countries. Once specific SWD site parameters have been inserted in the model, the results must be carefully reviewed and when possible compared to other LFG models for similar SWD sites. LFG generation and collection is a function of time and can vary widely over the life of a project so it is important to develop LFG projections for multi-year periods. These projections help with project design and sizing and in selecting the best technology and use for LFG. Although LFG modeling is an established practice, a degree of uncertainty exists. Unrealistic models can lead to investment in an uneconomical project and missed project opportunities. It is important for an interested industrial facility to develop a reasonable LFG model while understanding that LFG quantities predicted by the model will likely differ from actual LFG quantities collected at the SWD site due to many unpredictable variables such as site operations, LFG collection system implementation, LFG collection system operations and maintenance activities, and leachate levels within the SWD site. Industrial facility personnel do not typically have the expertise to conduct a proper LFG model and should work with LFG professionals to evaluate LFG modeling.

Pipeline installation for direct-use project at Conestoga Landfill, PA

Pipeline Installation: For direct-use of LFG to be successful, the industrial facility should be located in close proximity to the SWD site. The further that LFG needs to be piped to an industrial facility, the more expensive the project in both capital and operating costs. However, the precise distance that is economically feasible to transport LFG depends primarily on the following factors: 1) the amount of LFG that can be collected, 2) the energy requirements of the industrial facility, and 3) the cost of the fuel being displaced by LFG. Another important consideration is the pipeline route. Routes through highly urban settings and those with a significant amount of rock located close to the surface can be time consuming, costly, and problematic. In many tropical climates, the pipeline can be installed above ground, which can save substantial costs. Support from local authorities and regulatory agencies is often a critical component in determining the successful outcome of the route and ultimately the project.

Landfill Gas Treatment: The industrial equipment burning LFG may have technical specifications that require LFG to be treated for the removal or reduction of water, siloxanes, and/or sulfur compounds. The equipment also may require additional compression of LFG if high-pressure delivery is needed. The more processing required of LFG, the more expensive the project. Therefore, it is important that these specifications are established and clarified when evaluating the use of LFG. This is typically achieved by collecting an LFG sample for analysis during the assessment of a project.

Industry and SWD Site Compatibility: A project will be most successful when the energy demand of an industrial facility is relatively constant, and when the industrial facility can take the majority of the LFG output of the SWD site throughout the year (ideally 24 hours per day). The type of fuel(s) currently being used by the potential industrial facility is critical for understanding project economics, as LFG must be cost-competitive with existing and available fuel sources. LFG is a base-load energy source, meaning that it is constantly being generated and collected. If a potential utilization option has significant fluctuations in fuel use daily, weekly, or seasonally, an economically feasible project may be challenging. Some direct-use projects have overcome this issue, however, by utilizing both LFG and natural gas either simultaneously or alternately. The Industrial Facility Data Collection Form developed by GMI provides a helpful outline of information needed to evaluate an industrial facility for direct-use project compatibility (see http://www.globalmethane.org/tools-resources/tools.aspx#three).

Project Costs and Revenue and Funding Sources: In order for the successful implementation of a direct-use project, project costs, revenues, and financing options need to be explored and analyzed. Typical direct-use project costs include:

- Infrastructure Costs – LFG collection and control systems, pipeline construction (including costs of easements), compression and treatment systems, combustion equipment and control systems modifications (e.g. boiler or other equipment retrofit), and monitoring equipment;
- Operational Costs – Scheduled maintenance on the collection and control system and pipeline, and unscheduled maintenance due to impacts of nature, component failures, and changes in SWD site operations;
- Administrative Costs – Permits, legal, and contractual.

Direct-use projects provide a cost savings by offsetting current fuel costs. Environmental benefits such as green attributes and emission reduction credits may serve as important revenue sources (if applicable). Additional funding options such as grants, low-interest loans, and tax benefits should also be evaluated.

Contract Structure: In many cases, a third-party project developer is used to oversee and implement a direct-use project. However, GMI has observed several direct-use projects that are developed directly by the industrial facility. Once a viable LFG project has been identified, an LFG purchase agreement between the industrial facility and the SWD site owner (and potentially a third-party developer) should be negotiated. While many different ownership structures can be developed, an agreement should be structured in a way that benefits all parties as these agreements may last many years. Important components for an agreement include:

- How the SWD site owner, industrial facility, and potential third-party will benefit (e.g., whether revenues or savings will be paid on a fixed price basis or a price indexed to some other fuel or a combination of the two approaches).
- Equipment and infrastructure ownership, including the party responsible for making sure equipment is maintained and functioning properly.
- LFG quality and quantity issues – Who is responsible for the operation and maintenance of the collection and control system?
- Contract term as well as a term for which the project should be operated. (An industrial facility or third-party developer may also reasonably require a due diligence period to negotiate end user agreements, secure pipeline routes, etc.)
- The contract should also address any LFG delivery and consumption guarantees to ensure that a minimum amount of LFG can be expected by the industrial facility or that a minimum payment is received from the industrial facility. Many contracts include such provisions as "take or pay" or establish minimum or maximum amount to be delivered to the industrial facility.

How Can GMI Assist?

GMI brings together the collective resources and expertise of the international community to address technical and policy initiatives and facilitate LFG energy projects. GMI can:

- Identify potential LFG resources;
- Perform initial LFG generation and economic feasibility studies; and
- Facilitate technology transfer through training and workshops and project demonstrations.

LFG collection and beneficial use is a reliable and renewable fuel option that represents a largely untapped environmental and energy opportunity at thousands of SWD sites around the world. Cooperation with GMI will help ensure that more LFG reaches the energy market.

More information on LFG generation, collection, treatment, and utilization can be found in *the International Best Practices Guide for Landfill Gas Energy Projects* located on the GMI website at http://www.globalmethane.org/tools-resources/tools.aspx#ibpg.

LANDFILL METHANE OUTREACH PROGRAM

December 2009

Adapting Boilers to Utilize Landfill Gas: An Environmentally and Economically Beneficial Opportunity

Utilization of landfill gas (LFG) in place of a conventional fuel such as natural gas, fuel oil, or coal in boilers is an established practice with a track record of more than 25 years of success. In the United States, more than 60 organizations have switched to the use of LFG in their industrial, commercial, or institutional boilers, with more than 70 boilers operating with LFG, either alone or co-fired with other fuels. Boilers firing LFG range in size from 2 to more than 150 million British Thermal Units per hour (MMBtu/hr). Companies using LFG are saving money while protecting the environment. General Motors fires LFG in boilers at four of their manufacturing and assembly plants and reports that they have realized energy cost savings of about $500,000 per year at each of the four plants.

Mallinckrodt, Inc. Raleigh, NC

This fact sheet discusses the technical and engineering issues associated with using LFG in boilers designed to burn other fuels. The equipment and operational changes are relatively simple and use proven technologies, and dozens of firms can engineer and implement a conversion project.

Comparison of Landfill Gas and Natural Gas

Like natural gas, LFG's heating value is derived largely from methane, but unlike natural gas, LFG is comprised about 50 percent by volume of non-combustible gas, mostly carbon dioxide (CO_2). LFG is classified as a "medium Btu gas" with a heating value of about 500 Btu per cubic foot, about half that of natural gas. Therefore, the volume of LFG that must be handled by the fuel train and burner is twice that of natural gas. This means that modifications to the fuel train and burner are usually required to accommodate the higher overall gas flowrate for an equivalent natural gas heating value. The increased gas flow, however, does not have an appreciable effect on the design and operation of boiler components downstream of the burner. The added volume of non-combustible (inert) gas in LFG is equivalent to the inert gas entering a boiler when about six percent of the flue gas is recirculated to the boiler. Flue Gas Recirculation (FGR) is a widely applied technique for reducing nitrogen oxide (NO_x) emissions from natural gas-fired industrial and commercial boilers, and boilers can typically operate at recirculation rates of 20-25 percent without adversely affecting boiler heat transfer and efficiency. This comparison illustrates that the increased flow of LFG as compared to natural gas will not adversely affect boiler operation, although the burner, controls, and fuel train will require some modifications.

Burner, Control, and Fuel Train Modifications

Mallinckrodt, Inc. Raleigh, NC

The equipment for retrofitting a boiler to burn LFG is commercially available, proven, and not overly complex. The decisions that must be made during engineering and design are, however, site-specific and may be somewhat involved. For example, some installations have retained the original burner but modified it for LFG (e.g., by installing separate LFG fuel train and gas spuds) while maintaining the existing natural gas fuel train and gas ring to permit LFG/natural gas co-firing. Other installations have replaced the entire burner, controls, and fuel train with a dual-fuel burner and dual-fuel trains specifically designed to handle medium Btu gas. In general, the decision to furnish all new equipment is made based on the owner's preference or because the existing burner and controls are nearing the end of their useful lives. Additional analysis may be required to determine the amount of LFG compression that is provided versus the modifications needed for the burner and gas train.

Because LFG is typically a wet gas often containing trace corrosive compounds, the fuel train and possibly some burner "internals" should be replaced with corrosion-resistant materials. Stainless steel has typically been the material selected.

The controls associated with fuel flow and combustion air flow need to be engineered to cope with the variable heat content of LFG. The complexity of the burner management system will depend upon whether the boiler is to be co-fired with natural gas or oil and whether the boiler is to be co-fired at all times or if there will be times when it will be fired with LFG only. Today's modern controls, fast-responding oxygen analyzers, and responsive flame sensors make it possible to fire LFG with the same level of safety that is characteristic of current natural gas systems.

Boiler Deposits and Boiler Cleaning

In recent years, a family of organo-silicon compounds, known as siloxanes, commonly found in detergents, shampoos, deodorants, and cosmetics, have gradually found their way into the solid waste stream and into LFG. Their quantity in LFG is small and varies with the age of the landfilled material. When LFG is burned, the siloxanes are oxidized to silicon oxide—the primary chemical compound in sand. After firing boilers for an extended period with LFG, operators report a thin coating of white powder, described as similar to talcum powder, on some of the boiler tubes and substantial accumulations of the white powder on portions of the boiler floor. Where the material collects and how much of it accumulates is likely to be a function of the velocity patterns in the boiler and the siloxane concentrations in the LFG. One firetube boiler operator reported no deposits at all, probably due to the high flue gas velocity that is characteristic of the firetube boiler configuration.

Operators' experiences to date indicate that annual cleaning is sufficient to avoid operational problems related to silicon oxide accumulation. More frequent cleaning may be necessary as future installations encounter higher LFG siloxane concentrations or when low gas velocities exist in the boiler, either because of boiler design or continuous operation well below full capacity. In all cases, the silicon oxide powder is easily removed from surfaces by brushing or water washing.

Mallinckrodt, Inc. Raleigh, NC

Other Considerations

In designing and assessing the economic feasibility of projects utilizing LFG in boilers, several factors in addition to the boiler retrofit must be considered. For example, the quantity of LFG available must be considered and compared to the facility's steam needs and boiler capacities. Factors such as pipeline right-of-way issues and the distance between the landfill and the boiler will influence costs and the price at which LFG can be delivered and sold to the boiler owner. Because LFG is generally saturated with moisture, gas treatment is needed before the LFG is introduced into the pipeline and subsequently the boiler, to avoid condensation and corrosion. Additionally, condensate knock-outs along the pipeline are necessary as condensation in the main pipeline can cause blockages. Fortunately, the level of LFG clean-up required for boiler use is minimal, with only large particle and moisture removal needed. Other compounds in LFG, such as siloxanes, do not damage boilers or impair their function. Generally, LFG clean-up and compression systems are located at the landfill and are often installed by a developer rather than by the boiler owner. LFG compression provided at the landfill must be sufficient to compensate for pipeline pressure losses and provide sufficient pressure at the boiler to permit proper function of the fuel controls and burner. Proper attention to burner selection or burner modification for low-pressure operation can minimize the LFG compression costs.

Is My Boiler a Candidate for Landfill Gas Retrofit?

Virtually any commercial or industrial boiler can be retrofitted to fire LFG, either alone or co-fired with natural gas or fuel oil. The firing profile is a primary consideration, regardless of the boiler type, since the fuel cost savings associated with LFG must offset the costs of the LFG recovery (if a LFG collection system is not yet in place), the gas clean-up equipment, and the pipeline. Operation at substantial load on a 24-hour/7 day-per-week basis or something approaching continual operation is generally important to the economic viability of a potential project.

Both the smaller, lower-pressure firetube package boilers and larger, higher-pressure watertube package boilers are already in operation with LFG. Older field-erected brick set boilers have also been retrofitted for LFG fuel. Many major boiler manufacturers, such as Cleaver Brooks, Babcock &

Wilcox, Nebraska, and ABCO, are represented in the population of boilers that have been converted for LFG service. Similarly, leading burner manufacturers (e.g., Todd, North American, and Coen) have provided specially designed LFG burners or have experience modifying standard natural gas burners for LFG service.

Mallinckrodt, Inc. Raleigh, NC

Examples of Successful Boiler LFG Energy Projects

NASA Goddard Space Flight Center. In early 2003, NASA's Goddard Space Flight Center in Greenbelt, Maryland, began firing LFG in two Nebraska watertube boilers, each capable of producing 40,000 pounds per hour of steam. The gas is piped approximately five miles from the Sandy Hill Landfill to the boiler house at Goddard. NASA modified the burners and controls to co-fire LFG, natural gas, and oil; however, LFG provides the total firing requirement for approximately nine months of the year. Later, a third boiler also began utilizing LFG. NASA estimates an annual savings of more than $350,000. Current NASA plans call for LFG use to continue for at least 10 years, with a possible extension to 20 years. LMOP Partners Toro Energy and CPL Systems developed and implemented the project.

Cone Mills White Oak Plant. The LFG retrofit project at textile manufacturer Cone Mills' plant in Greensboro, North Carolina involved a very old (circa 1927) field-erected brick set boiler. In this instance, the developers chose to install two new, multi-fuel burners supplied by Coen Company, Inc. Full operation began in early 1997, with a steaming capacity of 30,000 pounds per hour from the LFG fuel. Additional steam is provided as needed by co-firing with natural gas or fuel oil. The gas is supplied to the Cone Mills plant via a three-mile pipeline originating at Greensboro's White Street Landfill. The project is a partnership between the City of Greensboro, Duke Solutions (now part of Ameresco, Inc.), and Cone Mills.

Information about additional projects can be found at the project profiles section of the LMOP Web site at www.epa.gov/lmop/projects-candidates/profiles.html. The photographs in this document depict a boiler retrofitted to burn LFG, courtesy of Mallinckrodt, Inc. in Raleigh, North Carolina.

Where Can I Obtain Further Information?

LMOP is a voluntary program that helps landfill owners, project developers, and communities develop LFG energy projects. LMOP offers technical support that includes finding a landfill, estimating gas generation, analyzing project economics, and providing other tools to help landfill owners and operators realize their facility's LFG use potential. For more information, visit the LMOP Web site at www.epa.gov/lmop/.

Global Methane Initiative

Industrial Facility
Data Collection Form

Information collected on this form is intended to assist in the evaluation of an industrial facility for the potential utilization of landfill gas (LFG) as a fuel.

Date:

Form completed by:

FACILITY CONTACT INFORMATION

Facility name:

Facility address and country:

Facility owner:

Facility contact name:

Facility contact phone number(s):

Facility contact email:

FACILITY INFORMATION

What does the facility produce or what is the primary purpose of the facility?

What is the total electrical demand (e.g., MW and MW-hours/year) of the facility and the current average cost of electricity (e.g., $/MW-hour)?

List the fuel(s) used at the facility and related information (attach additional sheets if necessary):

FUEL (natural gas, propane, coal, etc.)	**ANNUAL CONSUMPTION** (e.g., MMBTU/yr, GJ/yr, liters, etc.)	**FUEL COST** ($/GJ, $/liter, etc.)

List stationary equipment and number of units that burn fuel (e.g., boilers, process heaters, kilns, etc.):

BOILER OR PROCESS HEATER IDENTIFIER (name, number, etc.)	**HOURS OF USE OR TYPE OF OPERATION** (e.g., continuous, emergency, 8 hours/day, etc.)	**BOILER RATING** (MW, kg/hr steam, MJ/hr, etc.)	**CURRENT FUEL**	**BOILER TYPE** (fire-tube, water-tube, stoker, pulverized coal, etc.)	**IS THE UNIT USED FOR ELECTRICAL GENERATION?**

Please describe any processes where the combustion exhaust comes into direct contact with a product.

Please describe variations in energy use. Are there significant variations seasonally, daily, hourly? If so, please quantify the variation in energy use if possible (e.g., 11 percent more natural gas is purchased between November and March than the rest of the year).

Solid Waste Disposal Site
Data Collection Form

Information collected on this form can be used to analyze the potential for implementation of a landfill gas energy project.

Date:

Form completed by:

SWD SITE DETAILS AND LOCATION

Site name:

Physical address:

City, postal code:

Country:

Latitude/longitude:

SWD SITE OWNER CONTACT INFORMATION

SWD Site Owner:

Address:

Contact person and title:

Phone and email:

SWD SITE OPERATOR CONTACT INFORMATION (if different than owner)

SWD Site Operator:

Address:

Operator contact and title:

Phone and email:

LOCAL AND REGIONAL SUPPORT

Local / municipal agreement or interest in pursuing landfill gas project: YES ☐ NO ☐

Type(s) of cooperation sought to advance project:

- Investor build, own, operate: YES ☐ NO ☐
- Partnership: YES ☐ NO ☐
- Technical assistance: YES ☐ NO ☐

Is the project willing to consider carbon financing? YES ☐ NO ☐

- If yes, does the project owner already have an agreement (or contract) to sell its carbon credits? YES ☐ NO ☐

SWD SITE DESIGN INFORMAITON

SWD site type (sanitary landfill, controlled landfill/dump, open dump):

Area (designated area for waste placement - in hectares):

Waste-in-place (cubic meters or tonnes):

Waste-in-place year:

Planned capacity (cubic meters or tonnes):

Average waste depth (meters):

Year site began accepting waste:

Year site closed or will close:

Describe the leachate collection and removal system (if any):

SWD SITE OPERATIONAL INFORMATION

Waste Sources. Please list known or estimated waste composition percentages by waste <u>source</u> received at the SWD site. Waste material sources generally fall into two main categories: municipal waste and industrial waste. Municipal waste is generated at single-family homes, apartment buildings and light-duty commercial businesses such as restaurants, office parks and shopping malls. Industrial waste is generated at heavy-duty commercial businesses, including manufacturing centers, construction and demolition sites, and in sewage sludge processing. Total must equal 100%.

WASTE SOURCE	PERCENT OF WASTE STREAM
Municipal (households, light-duty commercial)	
Industrial (heavy-duty commercial, construction and demolition, sludge)	
Unknown (waste sources not identifiable)	
TOTAL	100%

Waste Types. Please list known or estimated waste composition percentages by waste type received at the site. There are many different types of waste materials. Please delineate out the waste materials by type with as great of detail as information is available. Under each main waste type category there is an opportunity to list more detailed waste type data if available. If detailed information in not available, please list known or estimated waste type quantities of the main categories (i.e. food waste, garden and park waste, etc.). Please attach additional information if necessary. Total must equal 100%.

WASTE TYPES	PERCENT OF WASTE STREAM	
1) Food Waste		
2) Garden and park waste		
3) Wood		
4) Paper		
5) Textiles		
6) Rubber, leather, bones, straw		
Other organics		
7a) Diapers, sanitary napkins		
7b) Toilet paper		
7c) Other		
Total other organics (total 7a-7c)		
Inert (plastics, metals, glass and ceramics, etc.)		
8a) Plastics		
8b) Metals		
8c) Glass and ceramics		
8d) Construction and demolition		
8e) Other		
Total Inert (total 8a-8e)		
TOTAL (all categories)	100%	

SWD SITE OPERATIONAL INFORMATION (continued)

Annual Waste Acceptance Data. Please provide specific waste acceptance quantities for each year the SWD site accepted waste. Please add additional lines or attach a separate document if more space is needed.

Source of Waste Acceptance Data (scales, estimates, etc.)	**Year**	**Waste Accepted** (cubic meters or tonnes)

SWD SITE OPERATIONAL INFORMATION (continued)

Describe how the site measures waste acceptance rates (i.e. truck scales, vehicle counts, annual growth rates, estimates, no measurement, other)?

Is the waste covered at the end of each working day? Material used?

Does the site apply a thicker layer of waste cover material (intermediate cover) to portions/sections of the SWD site that are not currently being used? Material used?

Does the site utilize a focused working face for waste disposal and/or have a strategic fill plan?

Do closed portions of the site have a permanent final capping system in place? Material used?

Does the site have a bottom liner? Material used?

Are the waste materials compacted? Equipment used (compactor, bulldozer)?

Describe waste filling process (i.e. large shallow lifts, small deep lifts):

Is there evidence of or is there a history of fires at the site (i.e. surface or subsurface)?

Describe waste scavenging and recycling practices (if any):

Describe site security or access controls (i.e. fence, security guards):

What other waste management practices are in place at the site or adjacent to the site (i.e. recycling, composting, waste treatment, anaerobic digestion, or conversion)?

Other SWD site conditions/operational practices to note:

SWD SITE LANDFILL GAS COLLECTION SYSTEM INFORMATION

Is a landfill gas collection and control system in place?

If yes, is the collection system actively collecting or passively venting the landfill gas?

Is the landfill gas collection system required by any regulation or law (if yes, explain requirements/applicable law)?

Types (vertical or horizontal) and quantities of landfill gas extraction wells:

Average depth of landfill gas extraction wells (meters):

Landfill gas collection rate (m3/hr):

Methane content of the landfill gas (percent by volume):

Potential/viable landfill gas utilization options or interests - are any industries nearby?

Additional details on the landfill gas collection and control system?

OPERATIONAL, UNDER CONSTRUCTION, PLANNED, OR SHUTDOWN LANDFILL GAS PROJECT INFORMATION

Project Type	**Status of Project Development** (Planned, In Construction, Operational, or Shutdown)	**Year Project Began Operation or Expected to Begin Operation**	**Landfill Gas Flow to Project** (enter value and units (e.g. m^3/hr)	**What is the Rated Capacity of the Landfill Gas Flare and Utilization Equipment?**	**Additional Project Details** (i.e. landfill gas end-users, size, amount of electricity produced, number of flares/engines, reason for shut-down, financial incentives/green tariff)
Open Flare					
Enclosed Flare					
Electricity Generation					
Other Type of Landfill Gas Utilization (i.e. boiler, heater, pipeline injection)					

If there are other planned, operational, or shutdown projects at this site, please copy this sheet to describe additional projects.

International Unit Conversions

DISTANCE/LENGTH

- 1 meter = 3.28 feet
- 1 inch = 25.44 mm
- 1 inch = 2.54 cm
- 1 yard = 0.914 m
- 1 km = 3,281 feet
- 1 km = 0.62 miles
- 1 mile = 1.6 km

Typical Conversions:

5 miles = 8.0 km
6 inches = 153 mm
8 inches = 204 mm
10 inches = 254 mm

TEMPERATURE

- F = (C x 9/5) + 32
- C = (F –32) x 5/9

Typical Conversions:

50°F = 10°C
100°F= 37.8°C
20°C = 68°F
55°C = 131°F

AREA

- 1 hectare (ha) = 2.471 acres

Typical Conversions:

10 ha =24.7 acres
50 ha =123.6 acres

WEIGHT

- 1 metric ton (Mg) =1 tonne= 1.1 US ton (Short Ton)

Typical Conversions:

2000 Mg = 2,204 short tons

DENSITY

Average MSW density range: 1,000-1,800 lb/yd3
Typical density = 1,200 lb/yd3 (712 kg/m3)

VOLUME

- 1 gallon = 0.003785 cubic meters
- 1 cubic meter = 264.17 gallons
- 1 gallon (US) = 3.7854 liters

FLOW

- scfm x 1.7=cubic meters per hour (m3/hr)
- m3/hr x 0.588=scfm

Typical Conversions:

100 scfm =170 m3/hr
500 scfm = 850 m3/hr
100 m3/hr = 59 scfm
500 m3/hr = 294 scfm

PRESSURE

- 1 mbar = 0.4015 inches of water

Typical Conversions:

149 mbar = 60 inches of water
30 mbar = 12.05 inches of water
10 mbar = 4.02 inches of water
10 inches of water = 24.9 mbar
30 inches of water = 74.7 mbar
60 inches of water = 149.5 mbar

THERMAL ENERGY (not for comparing heat input to electricity output for engines)

- LFG Heating Value (at 50% Methane): ~506 Btu/scf = ~18.63 MJ/Nm^3=~4,452 kCal/Nm^3
- 1Megawatt-thermal (MWth) = 3.41 MMBtu/hr
- 1 MWth = 3,600 Megajoules (MJ)

Typical Conversions:

500 kWth =1.7 MMBtu/hr
1 MWth = 3.4 MMBtu/hr
2 MWth = 6.8 MMBtu/hr
5 MWth = 17.1 MMBtu/hr

ELECTRIC GENERATION (32.5% efficiency)

Electric Output	Equivalency
1MWe (electrical output)	10.5 MMBtu/hr (heat input) 3.1 MWth 346 scfm @ 50% CH4 588 m^3/hr @ 50% CH4 11,160 MJ/hr
2MWe (electrical output)	21 MMBtu/hr (heat input) 6.2 MWth 692 scfm @ 50% CH4 1176 m3/hr @ 50% CH4 22,320 MJ/hr
3MWe (electrical output)	31.5 MMBtu/hr (heat input) 9.2 MWth 1038 scfm @ 50% CH4 1764 m3/hr @ 50% CH4 33,120 MJ/hr

TYPICAL LFG ENERGY PROJECT IN THE UNITED STATES

1 million tons of waste-in-place (WIP) = 300 scfm of LFG
1 million tons of waste-in-place (WIP) = 0.778 MWe