PDHonline Course C677 (3 PDH)

Landfill Gas-to-Energy Development

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1. Landfill Gas Energy Basics

Chapter Overview

Harnessing the power of landfill gas (LFG) energy provides environmental and economic benefits to landfills, energy users, and the community. In particular, LFG energy projects:

- Reduce emissions of greenhouse gases that contribute to global climate change.
- Offset the use of non-renewable resources, such as coal, oil, and natural gas.
- Help improve local air quality.
- Provide revenues for landfills and energy cost savings for users of LFG energy.
- Create jobs and economic benefits for communities and businesses.

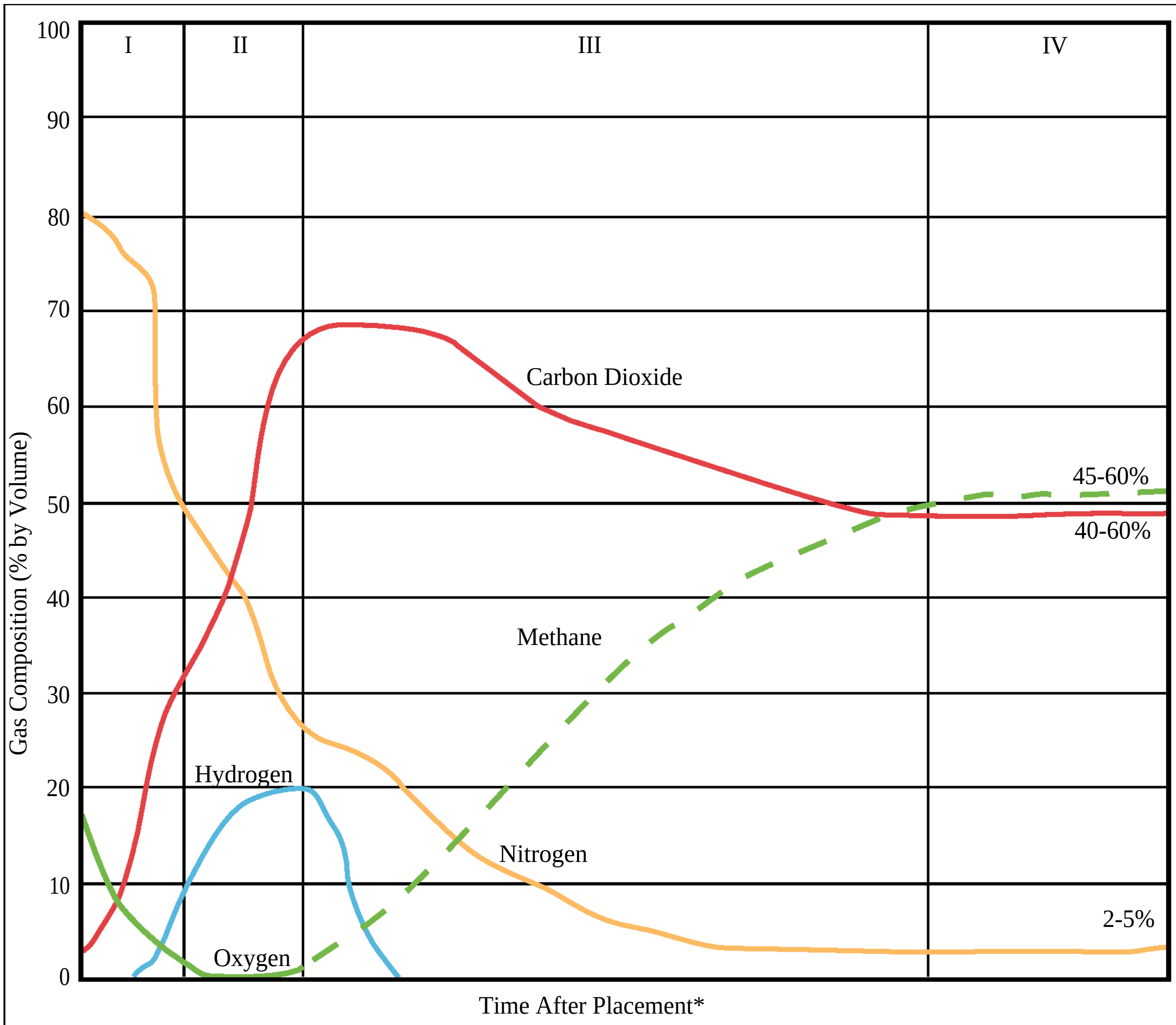
Landfill owners, energy service providers, businesses, state agencies, local governments, communities, and other stakeholders interested in developing this valuable resource can work together to develop successful LFG energy projects. The EPA Landfill Methane Outreach Program (LMOP) encourages and facilitates the development of environmentally and economically sound LFG energy projects by partnering with stakeholders and providing a variety of information, tools, and services.

This chapter provides a brief description of the source and characteristics of LFG and an overview of the basics of LFG collection, treatment, and use in energy recovery systems. This chapter also discusses the status of LFG energy in the United States and the benefits of LFG energy projects. It presents the basic steps of developing an LFG energy project along with descriptions of and links to the information, tools, and resources available from LMOP that may be helpful in LFG energy project development.

1.1 What Is LFG?

LFG is a natural byproduct of the decomposition of organic material in municipal solid waste (MSW) in anaerobic conditions. LFG contains roughly 50 percent methane and 50 percent carbon dioxide, with less than 1 percent non-methane organic compounds and trace amounts of inorganic compounds. When waste is first deposited in a landfill, it undergoes an aerobic (i.e., with oxygen) decomposition stage during which little methane is generated. Then, typically within less than one year, anaerobic (i.e., without oxygen) conditions are established and methane-producing bacteria decompose the waste and produce methane and carbon dioxide (as shown in Figure 1-1). Methane is a potent greenhouse (i.e., heat trapping) gas — over 20 times more potent than carbon dioxide. Landfills are the second largest human-caused source of methane in the United States, accounting for approximately 22 percent of U.S. methane emissions in 2008. For more information about national greenhouse gas emissions from landfills and other sources, see the U.S. Greenhouse Gas Inventory Report.

Figure 1-1. Changes in Typical LFG Composition After Waste Placement [1]



Phases

I. Aerobic
II. Anaerobic, Non-Methanogenic
III. Anaerobic, Methanogenic, Unsteady
IV. Anaerobic, Methanogenic, Steady

* Time scale (total time and phase duration) of gas generation varies with landfill conditions (e.g., waste composition and anaerobic state), but phase IV is generally reached in less than one year.

[1] Figure adapted from ATSDR 2008. Chapter 2: Landfill Gas Basics. In *Landfill Gas Primer - An Overview for Environmental Health Professionals.* Figure 2-1, p. 6. http://www.atsdr.cdc.gov/HAC/landfill/PDFs/Landfill_2001_ch2mod.pdf

Approximately 250 million tons of MSW were generated in the United States in 2008, with 54 percent of that deposited in landfills.[2] One million tons of MSW produces roughly 432,000 cubic feet per day (cfd) of LFG and continues to produce LFG for as many as 20 to 30 years after being landfilled. For more information on LFG modeling to estimate methane generation and recovery potential, see Chapter 2. Federal and/or state regulations require most large landfills to collect LFG and combust it, either by flaring or by using it in an LFG energy system. With a heating value of about 500 British thermal units (Btu) per standard cubic foot, LFG is a good source of useful energy. Many landfills collect and use LFG voluntarily to take advantage of this renewable energy resource while also reducing greenhouse gas emissions. For more information on regulations and permitting requirements, see Chapter 5. For more information about LFG and its effects on public health and the environment, see an LMOP page of frequently asked questions.

1.2 LFG Collection and Treatment

LFG collection typically begins after a portion of the landfill (known as a “cell”) is closed to additional waste placement. The most common method of LFG collection involves drilling vertical wells in the waste and connecting those wellheads to lateral piping that transports the gas to a collection header using a blower or vacuum induction system. Another type of LFG collection system uses horizontal piping laid in trenches in the waste. These systems are useful in deeper landfills and in areas of active filling. Some collection systems involve a combination of vertical wells and horizontal collectors. For more information about the types of LFG collection systems, see Chapter 3.

After collection, LFG can either be flared or used in an energy recovery system to combust the methane and other trace contaminants. Using LFG in an energy recovery system usually requires some treatment of the LFG to remove excess moisture, particulates, and other impurities. The type and extent of treatment depends on site-specific LFG characteristics and the type of energy recovery system employed. Boilers and most internal combustion engines generally require minimal treatment (e.g., dehumidification, particulate filtration, and compression). Some internal combustion engines and many gas turbine and microturbine applications also require siloxane removal using adsorption beds after the dehumidification step.[3] Figure 1-2 presents a diagram of an LFG energy project, including LFG collection, a fairly extensive treatment system, and an energy recovery system generating both electricity and heat. Most LFG energy projects produce either electricity or heat, although a growing number of combined heat and power (CHP) systems produce both.

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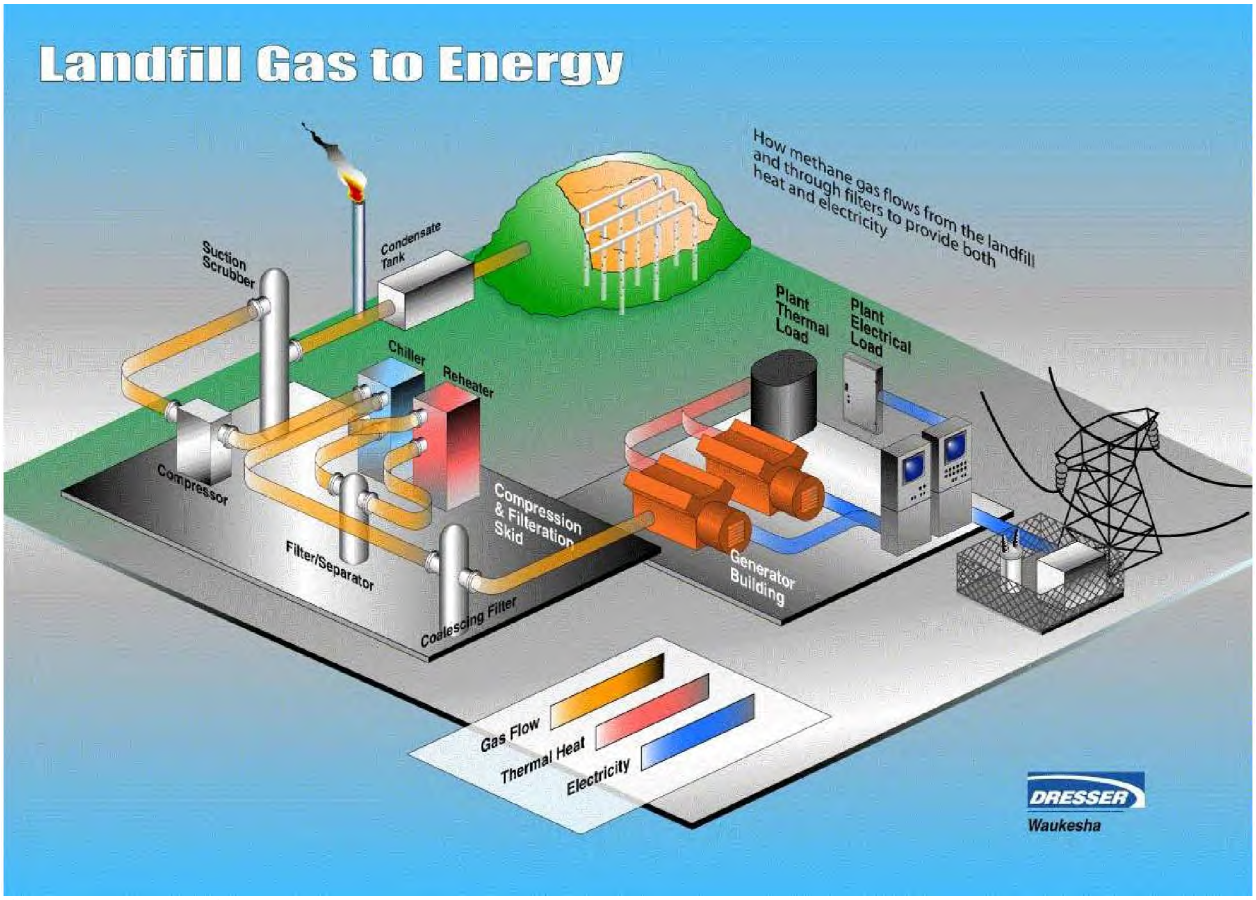
[2] Of the MSW generated in 2008, 33.2 percent was recovered through recycling or composting while 12.7 percent was combusted with energy recovery. Source: U.S. EPA. 2009. *Municipal Solid Waste Generation, Recycling, and Disposal in the United States — Facts and Figures for 2008.* EPA-530-F-09-021. Table 3, p. 8. http://www.epa.gov/epawaste/nonhaz/municipal/pubs/msw2008rpt.pdf

[3] Organo-silicon compounds, known as siloxanes, are found in household and commercial products that are discarded in landfills. Siloxanes find their way into LFG, although the amounts vary depending on the waste composition and age. When LFG is combusted, siloxanes are converted to silicon dioxide (the primary component of sand). Silicon dioxide is a white substance that collects on the inside of the internal combustion engine and gas turbine components, reducing the performance of the equipment and resulting in significantly higher maintenance costs. See Chapter 3 for further information.

Figure 1-2. LFG Collection, Treatment, and Energy Recovery

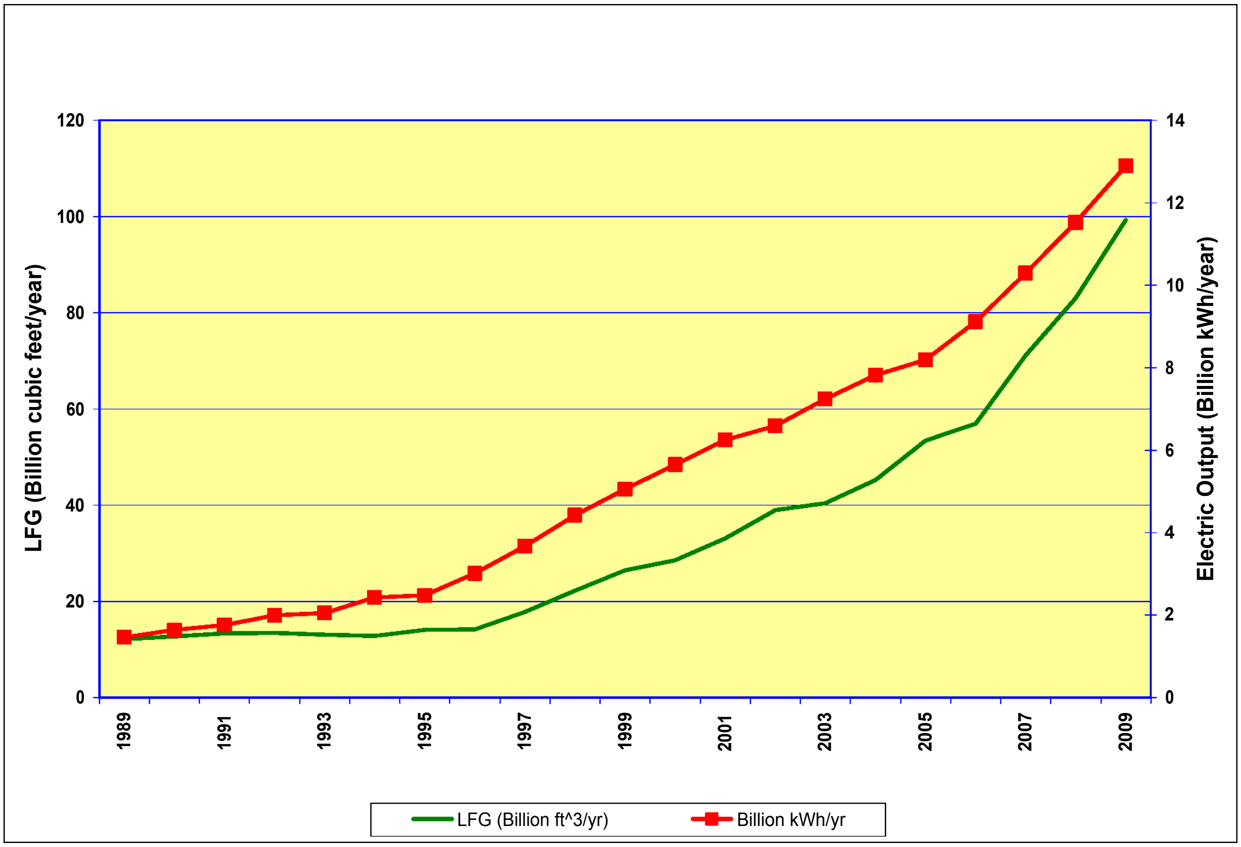


Graphic courtesy of Waukesha

1.3 LFG Energy Projects

Every million tons of MSW in a landfill is estimated to be able to produce approximately 432,000 cfd of LFG, which, through various technologies, could generate approximately 0.78 megawatts (MW) of power or provide 9 million Btu per hour (MMBtu/hr) of thermal energy. LFG energy projects first came on the scene in the mid- to late-1970s, but their implementation increased notably in the mid- to late-1990s as their track record for efficiency, dependability, and cost-savings was proven. The enactment of federal tax credits and regulatory requirements for LFG collection and control for larger landfills also helped spur this growth, as has increasing concern about climate change and demand for renewable energy. The growth in LFG energy project development steadily increased from 1989 to 2008, as depicted in Figure 1-3.

Figure 1-3. Growth in LFG Energy Project Output from 1989 to 2009: Electricity Generation and Direct Use



LMOP's Landfill and LFG Energy Project database, which tracks the development of U.S. LFG energy projects and landfills with project development potential, indicates that more than 500 LFG energy projects are currently operating in more than 40 states. Roughly two-thirds of these projects generate electricity, while one-third are direct-use projects in which the LFG is used for its thermal capacity. (Examples of direct-use projects include piping LFG to a nearby business or industry for use in a boiler, furnace, or kiln.) These 500+ projects are estimated to generate 13 billion kilowatt (kW)-hours of electricity and supply 100 billion cubic feet of LFG to direct end users and natural gas pipelines annually. More information about these projects as well as landfills with potential to support LFG energy projects is available on the Energy Projects and Candidate Landfills page of LMOP's website.

There are numerous examples of LFG energy success stories. Some of these involve LMOP Partners coming together to overcome great odds to bring a project to fruition; others involve the use of innovative technologies and approaches, while still others were completed in record time. To read about some of these projects, see LMOP's LFG Energy Project Profiles page and the Media and Press section of the website.

Electricity Generation

The majority (more than 70 percent) of the LFG energy projects that generate electricity do so by combusting the LFG in internal combustion engines. The three most commonly used technologies — internal combustion engines, gas turbines, and microturbines — can accommodate a wide range of project sizes. Gas turbines are more likely to be used for large projects, usually 5 MW or larger. Internal combustion engines are well-suited for 800 kW to 3 MW projects, but multiple units can be used together for projects larger than 3 MW. Microturbines, as their name suggests, are much smaller than turbines, with a single unit having between 30 and 250 kW in capacity, and thus are generally used for projects smaller than 1 MW. Small internal combustion engines are also available for projects in this size range. An LFG energy project may use multiple units to accommodate a landfill's specific gas flow over time. For example, a project might have three internal combustion engines, two gas turbines, or an array of 10 microturbines, depending on gas flow and energy needs. For more information about these technologies and others, see Chapter 3.

LFG energy CHP applications, also known as cogeneration projects, provide greater overall energy efficiency and are growing in number. In addition to producing electricity, these projects recover and beneficially use the heat from the unit combusting the LFG. LFG energy CHP projects can use internal combustion engine, gas turbine, or microturbine technologies.

Less common LFG electricity generation technologies include a few boiler/steam turbine applications, in which LFG is combusted in a large boiler to generate steam used by the turbine to create electricity. A few combined cycle applications have also been implemented. These combine a gas turbine that combusts the LFG with a steam turbine that uses steam generated from the gas turbine's exhaust to create electricity. Boiler/steam turbine and combined cycle applications tend to be larger in scale than the majority of LFG electricity projects that use internal combustion engines.

Direct Use

Direct use of LFG is often a cost-effective option when a facility that could use LFG as a fuel in its combustion or heating equipment is located within approximately 5 miles of a landfill; however distances of 10 miles or more can also be economically feasible in some situations. Some manufacturing plants have chosen to locate near a landfill for the express purpose of using LFG as a renewable fuel that is cost-effective when compared to natural gas. Figure 1-4 reflects the diversity of companies using LFG in their processes.

Figure 1-4. Look Who's Using LFG

The number and diversity of direct-use LFG applications is continuing to grow. Project types include:

- *Boilers*, which are the most common type of direct use and can often be easily converted to use LFG alone or in combination with fossil fuels.
- *Direct thermal applications*, which include kilns (e.g., cement, pottery, brick), sludge dryers, infrared heaters, paint shop oven burners, tunnel furnaces, process heaters, and blacksmithing forges, to name a few.
- *Leachate evaporation*, in which a combustion device that uses LFG is used to evaporate leachate (the liquid that percolates through a landfill). Leachate evaporation can reduce the cost of treating and disposing of leachate.

The creation of pipeline-quality, or high-Btu, gas from LFG is becoming more prevalent. In this process, LFG is cleaned and purified until it is at the quality that can be directly injected into a natural gas pipeline. Also growing in popularity are projects in which LFG provides heat for processes that create alternative fuels (e.g., biodiesel or ethanol). In some cases, LFG is directly used as feedstock for an alternative fuel (e.g., compressed natural gas [CNG], liquefied natural gas [LNG], or methanol). Only a handful of these projects are currently operational, but several more are in the construction or planning stages. LFG has also found a home in a few greenhouse operations. For more information about these technologies and others, see Chapter 3.

1.4 Environmental and Economic Benefits of LFG Energy Recovery

Developing LFG energy projects is an effective way to reduce greenhouse gas emissions, improve local air quality, and control odors. These projects also provide numerous other environmental and economic benefits to the community, the landfill, and the energy end user.

> The more than 500 currently operational LFG energy projects provide greenhouse gas reduction benefits that are equivalent to any one of the following:
>
> - Carbon sequestered annually by nearly 20 million acres of pine or fir forests.
> - Carbon dioxide emissions from 216 million barrels of oil consumed.
> - Annual greenhouse gas emissions from nearly 18 million passenger vehicles.
>
> These projects also provide enough energy to power more than 940,000 homes and heat more than 722,000 homes annually.

Environmental Benefits

MSW landfills are the second-largest human-caused source of methane emissions in the United States.[4] Given that all landfills generate methane, there is great opportunity to use the gas from as many landfills as possible for energy generation rather than letting it go into the atmosphere or flaring it without energy recovery. Methane is a very potent heat-trapping gas (more than 20 times stronger than carbon dioxide) so is a key contributor to global climate change. Methane also has a short atmospheric life (i.e., 10 to 14 years). Because methane is both potent and short-lived, reducing methane emissions from MSW landfills is one of the best ways to achieve a near-term beneficial impact in lessening the human impact on global climate change.

Direct Greenhouse Gas Reductions. During its operational lifetime, an LFG energy project will capture an estimated 60 to 90 percent of the methane created by a landfill, depending on system design and effectiveness. The captured methane is converted to water and carbon dioxide when the gas is burned to produce electricity or heat.[5]

Indirect Greenhouse Gas Reductions. Producing energy from LFG displaces the use of non-renewable resources (such as coal, oil, or natural gas) that would be needed to produce the same amount of energy. This avoids greenhouse gas emissions from fossil fuel combustion by an end user facility or power plant.[6]

[4] U.S. EPA. 2010. Chapter 8: Waste. In *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2008.* EPA-430-R-10-006. http://www.epa.gov/climatechange/emissions/usinventoryreport.html

[5] Carbon dioxide emissions from MSW landfills are not considered to contribute to global climate change because the carbon was contained in recently living biomass (i.e., is biogenic) and the same carbon dioxide would be emitted as a result of the natural decomposition of the organic waste materials if they were not in the landfill. This is consistent with international greenhouse gas protocols such as 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5: Waste, http://www.ipcc-nggip.iges.or.jp/public/2006gl/.

[6] The carbon in fossil fuels was not contained in recently living biomass; rather, the carbon was stored when ancient biomass was converted to coal, oil, or natural gas and would therefore not have been emitted had the fossil fuel not been extracted and burned. Carbon dioxide emissions from fossil fuel combustion are a major contributor to climate change.

Direct and Indirect Reduction of Other Air Pollutants. The capture and use of LFG at a landfill can benefit local air quality. Non-methane organic compounds that are present at low concentrations in LFG are destroyed during combustion, reducing possible health risks from these compounds. For electricity projects, the avoidance of fossil fuel combustion at utility power plants means that fewer pollutants such as sulfur dioxide (which is a major contributor to acid rain), particulate matter (a respiratory health concern), nitrogen oxides (which can contribute to local ozone and smog formation), and trace hazardous air pollutants are released into the air by utilities.

Equipment that burns LFG to generate electricity does generate some emissions, including nitrogen oxides. These emission levels depend on the type of equipment used. However, the overall environmental improvement achieved from LFG energy projects is significant because of the direct methane reductions, indirect carbon dioxide reductions, and direct and indirect reduction in other air pollutant emissions. There is also an energy benefit in avoiding the use of limited non-renewable resources such as coal and oil.

Other Environmental Benefits. Collecting and combusting LFG improves the quality of the surrounding community by reducing landfill odors, which are usually caused by sulfates in the gas. Gas collection can also improve safety by reducing migration of the gas to structures where the gas could accrue and cause explosion hazards.

Additional information about LFG environmental, safety, and public health concerns is found on an LMOP Frequently Asked Questions page. The LFG Energy Benefits Calculator can be used to estimate direct methane reductions, indirect carbon dioxide reductions, and equivalent environmental benefits for an LFG electricity or direct-use project.

Economic Benefits

For the Landfill Owner. Landfill owners can receive revenue from the sale of LFG to a direct end user or pipeline, or from the sale of electricity generated from LFG to the local power grid. (For more information about options when setting up a contract, see Chapter 5.) Depending on who owns the rights to the LFG and other factors, a landfill owner may also be eligible for revenue from renewable energy certificates (RECs), tax credits and incentives, renewable energy bonds, and greenhouse gas emissions trading. For more information about these items, see Chapter 4 and LMOP's online funding guide. All these potential revenue sources can help offset gas collection system and energy project costs for the landfill owner. For example, if the landfill owner is required to install a gas collection and control system, going the extra step of using the LFG as an energy resource — rather than installing a flare to combust the LFG without energy recovery — can help pay down the capital cost required for the control system installation.

> A public/private partnership to develop an electricity-generating LFG energy project at Catawba County's Blackburn Landfill in Newton, North Carolina, will generate revenues of $7.1 million for the County over the project's lifetime. Among other things, this will allow the County to keep tipping fees at their current level for at least 10 years. The LFG electricity provides Duke Energy (the electricity purchaser) with a renewable energy resource, and the greenhouse gas emission reductions are equivalent to the annual greenhouse gas emissions from 24,400 passenger vehicles.

For the End User. Businesses and other organizations, such as universities and government facilities, can save significantly on energy costs by choosing LFG as a direct fuel source in place of potentially more expensive fossil fuels whose price is subject to market volatility. Some end users can save millions of dollars over the duration of their LFG energy projects. Some companies report achieving indirect economic benefits through media exposure that portrays them as leaders in the use of renewable energy. For end users' perspectives about using LFG, see quotes from industry leaders.

> General Motors converted one of three powerhouse boilers at an Indiana plant to use LFG in addition to natural gas. The boiler produces steam to heat assembly plant and process equipment and to drive turbines to produce chilled water and pump water. The facility saves about $500,000 annually in energy costs; the greenhouse gas emission reductions equate to the carbon dioxide emissions from nearly 51,000 barrels of oil consumed.

> Springfield Gas and International Truck and Engine Corporation reached out to the community through public meetings, fact sheets, and individual visits to gain support for the permitting and development of a direct-use project in Springfield, Ohio. Five years after their efforts began, International began using LFG in place of natural gas in paint ovens, boilers, and other equipment, for an expected savings of $100,000 per year in fuel costs.

> The first LFG energy project implemented by BMW Manufacturing in South Carolina involved four gas turbines with heat recovery, which met 25 percent of the plant's electric needs and nearly all of its thermal needs. A few years later, BMW converted equipment in the paint shop to use even more LFG, so that this renewable resource now satisfies nearly 70 percent of the facility's energy consumption. BMW later replaced the four original gas turbines with two new turbines. BMW estimates its savings at $1 million per year.

For the Community. LFG energy project development can greatly benefit the local economy. Temporary jobs are created for the construction phase, while design and operation of the collection and energy recovery systems create long-term jobs. LFG energy projects involve engineers, construction firms, equipment vendors, and utilities or end users of the power produced. Some materials for the overall project may be purchased locally, and often local firms are used for construction, well drilling, pipeline installation, and other services. In addition, hotel rooms and meals for the workers provide a boost to the local economy. Some of the money paid to workers and local businesses by the LFG energy project gets spent within the local economy on goods and services, resulting in indirect economic benefits. In some cases, LFG energy projects have led new businesses (e.g., brick and ceramics plants), greenhouses, or craft studios, to locate near the landfill to use LFG. Such new businesses add depth to the local economy.

> Construction of a direct-use project using LFG from the Lanchester Landfill in Narvon, Pennsylvania, created over 100 temporary construction jobs, involved the purchase of local materials, and infused millions of dollars into the local economy.
>
> A direct-use project in Virginia requiring a 23-mile long pipeline to transport LFG to Honeywell provided jobs and revenue to the local town. For example, building the pipeline resulted in 22,000 hotel stays in Hopewell, Virginia.

The EnergyXchange Renewable Energy Center, located at the foot of the Black Mountains in western North Carolina, has brought national attention to the region and its artisans through a small-scale but far-reaching LFG energy project. Glass blowers, potters, and greenhouse students have benefitted from the local supply of LFG, through saved energy costs, education and hands-on experience, and recognition of their crafts. The artisans' savings have already exceeded $1 million.

The ecology club at Pattonville High School in Maryland Heights, Missouri, suggested to the school board that they consider using excess LFG from the nearby Fred Weber Landfill in the school's boilers. Feasibility analyses determined that the savings were worthwhile and a partnership was born. With a loan, a grant, and capital from Fred Weber, the direct-use project was brought to fruition, and the school saves about $27,000 per year.

Jobs and Revenue Creation

- A typical 3 MW LFG electricity project is estimated to have the following economic and job creation benefits during the construction year:
  - ► Add more than $1.5 million in new project expenditures for the purchase of generators, and gas compression, treatment skid, and auxiliary equipment
  - ► Directly create at least 5 jobs for the construction and installation of the equipment.
  - ► Considering the ripple effect resulting from new project spending, will increase the state-wide economic output by $4.3 million and employ 20 to 26 people throughout the state and local economies.
- A typical 1,040 standard cubic foot per minute (scfm) LFG direct-use project is estimated to have the following economic and job creation benefits during the construction year:

  5-mile pipeline:
  - ► Add more than $1.1 million in new project expenditures for the purchase of the pipeline, and gas compression, treatment skid, and auxiliary equipment.
  - ► Directly create at least 7 jobs for the installation of the pipeline and energy recovery equipment.
  - ► Considering the ripple effect resulting from new project spending, will increase the state-wide economic output by $2.9 million and employ 17 to 22 people throughout the state and local economies.

  10-mile pipeline:
  - ► Add more than $2.2 million in new project expenditures for the purchase of the pipeline, and gas compression, treatment skid, and auxiliary equipment.
  - ► Directly create at least 14 jobs for the installation of the pipeline and energy recovery equipment.
  - ► Considering the ripple effect resulting from new project spending, will increase the state-wide economic output by $5.3 million and employ 32 to 41 people throughout the state and local economies.

1.5 Steps to LFG Energy Project Development

The following section provides a basic overview of the steps involved in developing an LFG energy project. Landfill owners can use several mechanisms to implement projects in their communities and promote the use of LFG as a renewable energy resource. There are nine broad steps when implementing an LFG energy project:

1. *Estimate LFG Recovery Potential and Perform Initial Assessment.* In this first step, the landfill owner or other party would determine if the landfill site is likely to produce enough methane to support an energy recovery project. Screening criteria include whether the landfill contains at least 1 million tons of MSW, has a depth of 50 feet or more, and is open or recently closed. In addition, the site should receive at least 25 inches of precipitation annually. Landfills that meet these criteria are likely to generate enough gas to support an LFG energy project. It is important to note that these are only ideal conditions, and many successful LFG energy projects have been developed at smaller, older, and/or more arid landfills. Once it is determined that the energy recovery option is viable, the next step is to estimate gas flow. EPA's Landfill Gas Emissions Model (LandGEM) can provide a more detailed analysis of LFG generation potential. See Chapter 2.

2. *Evaluate Project Economics.* The next step in project development is to perform a detailed economic assessment of converting LFG into a marketable energy product such as electricity, steam, boiler fuel, vehicle fuel, or pipeline-quality gas. A variety of technologies can be used to maximize the value of LFG when producing these energy forms. The best configuration for a particular landfill will depend on a number of factors including the existence of an available energy market, project costs, potential revenue sources, and other technical considerations. LMOP's LFGcost-Web tool, available to LMOP Partners, can help with preliminary economic evaluation. See Chapters 3 and 4.

3. *Establish Project Structure.* Options for how to develop and manage an LFG energy project include:

   - The landfill owner can develop/manage the project internally.
   - The landfill owner can team with a project developer. The developer finances, constructs, owns, and operates the project.
   - The landfill owner can team with partners (e.g., equipment supplier, energy end user).

   LMOP can assist with project partnering by identifying potential matches and distributing requests for proposals (RFPs). See Chapter 6 for more information on project structures and evaluating project partners.

4. *Draft Development Contract.* If the project structure involves a partnership, the terms of the partnership should be formalized in a development contract, which includes determining which partner will own the gas rights and the rights to potential emissions reductions. The contract will also determine partner responsibilities including design, installation, operation, and maintenance. Contracting with a developer is a complex issue and each contract will be

different depending on the specific nature of the project and the objective and limitations of the participants. See Chapters 5 and 6.

5. *Assess Financing Options.* Financing an LFG energy project is one of the most important and challenging tasks facing a landfill owner or project developer. A number of potential financing avenues are available, including finding equity investors, obtaining loans from investment companies or banks, and issuing municipal bonds. Five general categories of financing methods may be available to LFG energy projects: private equity financing, project financing, municipal bond funding, direct municipal financing, and lease financing. For a full description of these financing mechanisms, see Chapter 4. In addition to financing options, there are a variety of financial incentives available at the federal and state level. Local governments are eligible for some of these incentives, which are described in detail in LMOP's funding guide: Funding Landfill Gas Energy Projects: State, Federal, and Foundation Resources.

6. *Negotiate Energy Sales Contract.* This contract exists between the LFG energy project owner and the end user and specifies the amount of gas or power to be delivered and at what price. An energy sales contract will determine the success or failure of the project since it secures the project's source of revenue. Therefore, successfully obtaining this contract is a crucial milestone in the project development process. Because contract negotiation is often a complex process, owners and developers should consult an expert for further information and guidance. Negotiating an energy sales contract involves the following steps: preparing a draft offer contract, determining utility or end user need for power or gas demand, developing project design and pricing, preparing and presenting a bid package, reviewing contract terms and conditions, and signing the contract. See Chapter 5.

7. *Secure Permits and Approvals.* Obtaining required environmental, siting, and other permits is an essential step in the development process. Permit conditions often affect project design and neither construction nor operation can begin until the appropriate permits are in place. The process of permitting an LFG energy project may take anywhere from six to 18 months (or longer) to complete, depending on the project's location and recovery technology. LFG energy projects must comply with federal regulations related to both the control of LFG emissions and the control of air emissions from the energy conversion equipment. Regulations promulgated under two separate federal acts, the Resource Conservation and Recovery Act (RCRA) and the Clean Air Act, address emissions from MSW landfills. During this phase of the project, the landfill owner should contact and meet with regulatory authorities to determine requirements and educate the local officials, landfill neighbors, and nonprofit and other public interest and community groups about the benefits of the project. Chapter 5 summarizes federal regulations and permitting requirements, and LMOP's State Resources page lists websites for state organizations that can provide useful information regarding state-specific regulations and permits.

8. *Contract for Engineering, Procurement, and Construction (EPC) and Operation and Maintenance (O&M) Services.* Constructing and operating LFG energy projects is a complex process, so it may be best managed by a firm with proven experience gained over the course

of implementing similar projects. Landfill owners that choose to contract with EPC and O&M firms should take the following steps: soliciting bids from EPC/O&M contractors, selecting the EPC/O&M contractor, and negotiating the contract. The selected EPC/O&M contractor conducts the engineering design, site preparation and plant construction, and startup testing. See Chapter 6.

9. *Install Project and Start Up.* The final phase of implementation is the start of commercial operations. This phase is often commemorated with ribbon-cutting ceremonies, public tours, and press releases. LMOP offers an online Toolkit containing templates and tips for these events.

1.6 LMOP Resources and Services

LMOP is a voluntary assistance and partnership program created by EPA in 1994 to reduce methane emissions by encouraging the recovery and use of LFG as a renewable, green energy resource. LMOP's website has become one of the main modes of providing LMOP Partners, others in the industry, and the public with basic information and keeping them abreast of the latest LFG energy–related advances and opportunities. LMOP has developed many publications and tools to assist those wishing to develop LFG energy projects or promote LFG to various audiences. LMOP also provides customized, direct assistance to individual Partners to address their needs.

Joining LMOP as a Partner or Endorser

Organizations partner with LMOP voluntarily to gain a greater understanding of LFG efforts and to build connections with other interested parties. EPA established five types of Partner programs (Industry, Energy, Community, State, and Endorser) to assist different sectors of the LFG field. LMOP works with landfill owners/operators, industry organizations, energy providers and marketers, state agencies, communities, end users, and other stakeholders to help them overcome barriers to LFG energy development. LMOP does so by providing access to technical assistance, conducting outreach, and fostering relationships between Partners. Basic information about current Partners, including contacts and areas of expertise, is posted on LMOP's website monthly for other Partners and the general public to see and potentially contact them (e.g., for their services or about their landfill). To join LMOP, organizations read, sign, and submit a memorandum of understanding (MOU) or agreement, electronic versions of which are available on the Join the Program page of LMOP's website.

Landfill and LFG Energy Project Database

LMOP's Landfill and LFG Energy Project database is the most comprehensive data repository for LFG energy projects and landfills with potential for energy recovery in the country. It is updated continually with information from LMOP Partners and other organizations in the industry. LMOP posts Excel files on the website for anyone to view and download. On the Web page, users can view data for a specific project type of interest, for landfills that are good candidates for energy project development, or for all projects and landfills in a single state. In addition to posted data, LMOP maintains a master database with some additional fields and can provide information from the database to address specific questions.

Direct Assistance for Developing LFG Energy Projects

LMOP offers direct assistance throughout the development of a project, from providing basic information about LFG energy in the early stages of project consideration, to preliminary analyses of project feasibility, to providing media support when the project reaches the construction or commercial operation phase. Services LMOP offers include:

- Matching landfills and end users. When assisting a landfill owner/operator or project developer, LMOP can help identify potential end users for the project. When assisting a potential end user, LMOP can search for nearby landfills that are good candidates for project development.
- Making preliminary estimates of recoverable methane using LFG models such as LandGEM and site-specific information on landfill waste acceptance.
- Assisting with preliminary technical and economic feasibility assessments for LFG energy project options. (Before entering into partnerships and agreements to develop an LFG energy project, interested parties will of course need to have a more detailed site-specific estimate performed by a professional with LFG energy experience.)
- Helping to locate project partners through networking opportunities and by distributing RFPs through listserv messages.
- Answering technical questions and providing information to help overcome barriers to LFG energy projects, including technical and permitting issues. LMOP can also attend meetings with stakeholders to address questions about LFG energy and foster positive interactions among landfill owners, developers, end users, regulatory agencies, community groups, and other stakeholders.
- Providing positive publicity for LFG energy projects by developing recognition materials for project ribbon-cuttings, publicizing a project through LMOP's newsletter, and recognizing outstanding Partners and projects via LMOP's annual awards.

Online Tools to Assist With Project Development

The LMOP Funding Guide, updated quarterly, lists many innovative funding programs and strategies that can help developers and landfill owners overcome financial barriers. These programs and strategies include loans, grants, low-interest loans, production incentives, tax credits, and exemptions from property, sales, and use taxes. The funding guide provides a narrative description of each resource listed, contact information, and links to each resource's Web page where application materials can be downloaded, if available.

LMOP's Interactive Conversion Tool allows a user to easily perform unit conversions, such as standard cubic feet per minute (scfm) to million standard cubic feet per day (mmscfd) or short tons of methane to metric tons of carbon dioxide equivalents. It can also be used to provide a very preliminary estimate of the LFG energy potential from a landfill, for example, by providing results in scfm of LFG or MW capacity based on an input of tons of waste-in-place.

LFG models, used to estimate a landfill's potential methane generation and recovery over time, are often available on line. These include EPA's LandGEM software to estimate methane for U.S. landfills, and LMOP's international LFG models that have been customized for other countries or regions.

LFGcost- Web, a model that can be used to provide a preliminary assessment of the economic feasibility of a variety of LFG energy project options for an individual landfill, is available to LMOP Partners on line. Users should have a good understanding of factors that influence LFG energy project costs and revenues before using this software. The online version includes several simplifying assumptions. If these assumptions are not representative of your landfill, LMOP can assist by providing an analysis that is more tailored to your landfill and potential project.

The LFG Energy Benefits Calculator enables users to estimate an LFG energy project's direct methane reductions, avoided carbon dioxide emissions (when LFG is used instead of a fossil fuel to generate electricity or fuel a process), and total greenhouse gas reductions. It also provides equivalent environmental and energy benefits for the current year. The calculator can be a useful tool when writing a press release or other media-based announcement regarding an LFG energy project.

LMOP's online Toolkit is designed to help LMOP Partners and others communicate LFG energy benefits and develop outreach materials. The toolkit features sample outreach tools (e.g., communication tips, talking points, checklists for ribbon-cutting and groundbreaking ceremonies, and press release templates) to help project partners share the good news about LFG energy projects with their community, employees, shareholders, customers, the media, and other stakeholders.

Documents

LMOP's Publications/Tools page provides access to technical and informational documents, including fact sheets and brochures. Examples include:

- A brochure specifically developed for potential corporate end users of LFG.
- A fact sheet providing information on adapting boilers to utilize LFG.
- LMOP's Power of Partnership brochure describes the program's purpose and goals, lists options, tools, and resources to help interested parties move forward with their own LFG utilization goals, defines LMOP's five Partner types, and offers four Partner success stories.

LMOP's website also provides a Frequently Asked Questions (FAQ) page for questions about the program itself, about LFG energy projects in general, and about how LFG affects public health, safety, and the environment.

Newsletters, E-mails, and Conferences

The *Gasette,* LMOP's online newsletter, includes articles about new LFG energy projects, industry trends, conferences, new regulations and incentives that affect or encourage LFG energy projects, and LFG energy advancement in the international community.

LMOP also sends timely LFG energy–related listserv messages to Partners and other interested parties to notify them of RFPs, upcoming events of interest, and funding opportunities. To receive these messages, submit the contact form from the LMOP website or contact LMOP directly.

LMOP's annual conference provides opportunities to network with other organizations in the LFG energy industry and learn about exciting projects, technologies, and innovative ideas presented during topical sessions and from exhibitors. The LMOP website has information on future conferences and presentations from previous conferences. The conference includes a Project Expo that showcases several landfills with LFG energy project development potential to developers and other interested parties.