State and Local
Climate and Energy Program

LOCAL GOVERNMENT CLIMATE AND ENERGY STRATEGY GUIDES

Landfill Gas Energy

A Guide to Developing and Implementing Greenhouse Gas Reduction Programs

Renewable Energy

U.S. ENVIRONMENTAL PROTECTION AGENCY
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EPA's Local Government Climate and Energy Strategy Series

The Local Government Climate and Energy Strategy Series provides a comprehensive, straightforward overview of greenhouse gas (GHG) emissions reduction strategies that local governments can employ. Topics include energy efficiency, transportation, community planning and design, solid waste and materials management, and renewable energy. City, county, territorial, tribal, and regional government staff and elected officials can use these guides to plan, implement, and evaluate climate and energy projects.

Each guide in the series provides an overview of project benefits, policy mechanisms, investments, key stakeholders, and other implementation considerations. Examples and case studies highlighting achievable results from programs implemented in communities across the United States are incorporated throughout the guides.

While each guide stands on its own, the entire series contains many interrelated strategies that can be combined to create comprehensive, cost-effective programs that generate multiple benefits. For example, efforts to improve energy efficiency can be combined with transportation and community planning and design programs to reduce GHG emissions, decrease the costs of energy and transportation for businesses and residents, improve air quality and public health, and enhance quality of life.

LOCAL GOVERNMENT CLIMATE AND ENERGY STRATEGY SERIES

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- Energy Efficiency in Local Government Operations
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- Energy-Efficient Product Procurement
- Combined Heat and Power
- Energy Efficiency in Water and Wastewater Facilities

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EXECUTIVE SUMMARY

Developing and Implementing Renewable Energy Programs

A growing number of local governments are turning to renewable energy as a strategy to reduce GHGs, improve air quality and energy security, boost the local economy, and pave the way to a sustainable energy future. Renewable energy resources—such as solar, wind, biomass, hydropower, and landfill gas—reduce GHG emissions by replacing fossil fuels. Renewables also reduce emissions of conventional air pollutants, such as sulfur dioxide, that result from fossil fuel combustion. In addition, renewable energy can create jobs and open new markets for the local economy, and can be used as a hedge against price fluctuations of fossil fuels. Local governments using renewable energy can demonstrate leadership, helping to spur additional renewable energy investments in their region.

Local governments can promote renewable energy by using it to help meet their own energy needs in municipal operations, and by encouraging its use by local residents and businesses. The renewable energy guides in this series present three strategies that local governments can use to gain the benefits of renewables: purchasing green power (see the guide on green power procurement), generating energy from renewable sources on-site (see the guide to on-site renewable energy generation), and generating renewable energy from landfill gas.

Use of Landfill Gas as a Renewable Energy Resource

This guide describes how local governments and communities can achieve energy, environmental, health, and economic benefits by using landfill gas (LFG) recovered from municipal solid waste landfills as a source of renewable energy. As solid waste decomposes in landfills, a gas is emitted that is approximately 50 percent methane (CH_4) and 50 percent carbon dioxide (CO_2), both of which are GHGs (U.S. EPA, 2011a). LFG energy technologies capture CH_4 to prevent it from being emitted to the atmosphere, and can reduce landfill CH_4 emissions by between 60 and 90 percent (depending on project design and effectiveness) (U.S. EPA, 2011a). This guide describes technologies and strategies for recovering and using LFG as an energy resource. It is designed to be used by local governments, regulatory and planning agencies, developers, contractors, project partners, energy service companies, and end users, including business and industrial customers who work with project owners.

Readers of the guide should come away with an understanding of options to recover and use LFG from landfills, a clear idea of the steps and considerations involved in developing and implementing LFG energy projects, and an awareness of expected costs and financing opportunities.

RELATED STRATEGIES IN THIS SERIES

- **Renewable Energy: *Green Power Procurement***

  Green power is a subset of renewable energy that is produced with no GHG emissions, typically from solar, wind, geothermal, biogas, biomass, or low-impact small hydroelectric sources. EPA recognizes LFG as a green power source, and many local governments are purchasing LFG energy products from private landfill or LFG energy project owners and selling them to commercial and residential customers to increase the use of renewable energy and reduce GHG emissions.

- **Renewable Energy: *On-Site Renewable Energy Generation***

  Local governments can implement on-site renewable energy generation by installing wind turbines, solar panels, and other renewable energy generating technologies, including LFG. Installing LFG equipment at municipal facilities—and providing incentives to local businesses and residents to do the same—can also be an effective way to demonstrate a local government's commitment to meeting community GHG emission reduction goals.

- **Energy Efficiency: *Combined Heat and Power***

  Combined heat and power (CHP), also known as cogeneration, refers to the simultaneous production of electricity and thermal energy from a single fuel source. LFG can be a fuel source for CHP systems, either on-site or piped to nearby industrial or commercial users to provide a second revenue stream for the project.

The guide describes the benefits of landfill gas energy (section 2); technologies for converting LFG into energy (section 3); key participants and their roles (section 4); the policy mechanisms that local governments use to promote LFG energy projects (section 5); implementation strategies for effective projects (section 6); costs and financing opportunities (section 7); federal, state, and other programs that may be able to help local governments with information or technical assistance (section 8); and two case studies of local governments that have successfully developed comprehensive LFG energy projects (section 9). Additional examples of successful implementation are provided throughout the guide.

Relationships to Other Guides in the Series

Local governments can use other guides in this series to develop robust climate and energy programs that incorporate complementary strategies. For example, local governments can combine efforts to use LFG energy with **green power procurement**, **on-site renewable energy generation**, and use of LFG in **combined heat and power** to achieve additional economic, environmental, and social benefits associated with the use of renewable energy, energy efficiency measures, and reduced GHG emissions.

See the box on page v for more information about these complementary strategies. Additional connections to related strategies are highlighted in the guide.

Landfill Gas Energy

1. OVERVIEW

Many local governments across the United States are achieving energy, environmental, health, and economic benefits by utilizing technologies that capture methane (CH_4) from municipal solid waste (MSW) landfills, preventing it from being emitted to the atmosphere, and using it to produce various forms of energy, including electricity, boiler fuel, steam, alternate vehicle fuel, and pipeline quality gas (U.S. EPA, 2011a). Landfill gas (LFG) energy projects employ proven technologies to capture LFG, a product of solid waste decomposition in landfills that contains approximately 50 percent CH_4 and 50 percent carbon dioxide (CO_2), both of which are greenhouse gases (GHGs).[1] With a heating value of about 500 British thermal units (Btu) per standard cubic foot (scf), LFG is a good source of energy.

METHANE FROM MSW LANDFILLS

CH_4 is a hydrocarbon and the primary component of natural gas. It is also a potent GHG with a global warming potential more than 20 times that of CO_2. MSW landfills are the third-largest source of man-made CH_4 emissions in the United States, accounting for about 17 percent of the country's CH_4 emissions in 2009. Despite its potency as a GHG, CH_4 has a relatively short atmospheric lifetime of 9-14 years, meaning projects that capture CH_4 from landfills offer a significant opportunity to mitigate atmospheric concentrations of CH_4 in the near-term.

Source: U.S. EPA, 2011a.

EPA estimates that as of July 2011, approximately 560 LFG energy projects were operational in the United States. These projects generate approximately 1,730 megawatts (MW) of electricity per year and deliver 310 million cubic feet (ft^3) per day of LFG to direct-use applications. An additional 510 landfills present attractive opportunities for project development. If developed, these landfills have the potential to generate an additional 1,170 MW of electric power or 590 million ft^3 per day of LFG (U.S. EPA, 2011b). Counts of these operational and potential LFG energy projects by state are illustrated in Figure 1 on page 2.

EPA'S LANDFILL METHANE OUTREACH PROGRAM

The EPA Landfill Methane Outreach Program (LMOP) is a voluntary assistance program that helps reduce GHGs from landfills by encouraging the recovery and use of LFG as a renewable energy resource. Launched by EPA in 1994, LMOP forms partnerships with communities, local governments, utilities, power marketers, states, project developers, and nonprofit organizations to overcome barriers to project development. For additional information, please visit the LMOP Web site: *http://www.epa.gov/lmop/*.

Source: U.S. EPA, 2011a

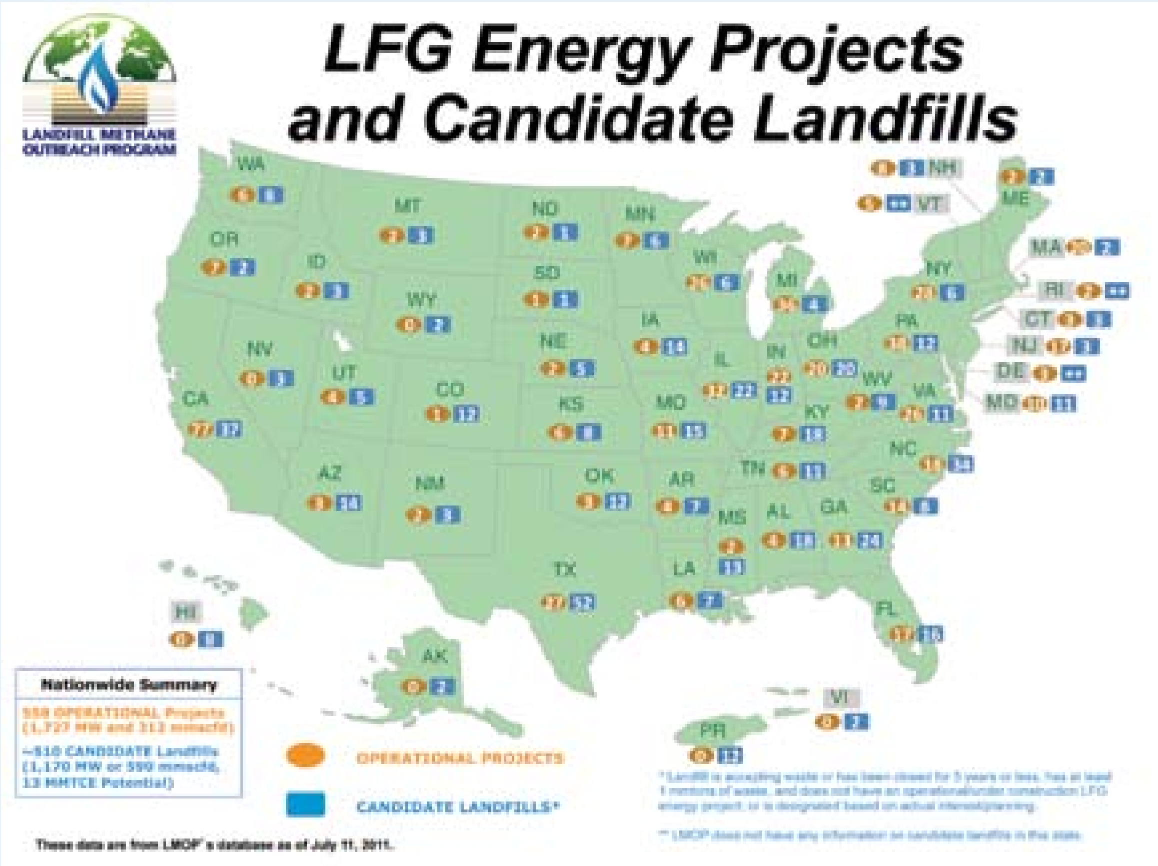
Most MSW landfills are owned either by local governments or the private sector. Similarly, the LFG energy projects installed at local government-owned landfills can be owned and operated by the local government or a private developer hired by the local government—both entities are referred to as "LFG energy project owners" in this guide.

ENERGY FROM LFG AS A GREEN POWER SOURCE

Because of its superior environmental profile compared to conventional energy, EPA recognizes LFG as a green power source. For more information on green power, see EPA's Green Power Procurement guide in the Local Government Climate and Energy Strategy Series. For more information on generating renewable energy at local government facilities, see the guide on On-site Renewable Energy Generation.

[1] LFG contains approximately 50% CH_4 and 50% CO_2. Small amounts of non-methane organic compounds (NMOCs) and trace amounts of inorganic compounds comprise less than 1% of the mix (U.S. EPA, 2011a). CO_2 that is emitted from LFG energy projects is not considered to contribute to global climate change because the carbon was contained in recently living biomass and would have been emitted through the natural decomposition process.

FIGURE 1. LANDFILL GAS ENERGY PROJECTS AND CANDIDATE LANDFILLS



Source: U.S. EPA, 2011b.

This guide highlights the local government and community benefits of LFG energy projects at local government-owned landfills. It provides information on how local governments have planned and implemented LFG energy projects to utilize CH_4, offers information on sources of funding, and presents case studies. Additional examples and information resources are presented in Section 10 on page 20, *Additional Examples and Information Resources*.

2. BENEFITS OF LANDFILL GAS ENERGY

Capturing LFG and using it as an energy resource can produce significant energy, environmental, economic, and other benefits. Specifically, using LFG helps local governments to:

- **Reduce emissions of GHGs.** MSW landfills are the third-largest human-generated source of CH_4 emissions in the United States, releasing an estimated 27.5 million metric tons of carbon equivalent (MMTCE) in 2009 alone (U.S. EPA, 2011a). An LFG energy project can reduce CH_4 emissions from a landfill by between 60 and 90 percent, depending on project design and effectiveness (U.S. EPA, 2011a). The annual CH_4 (landfill methane) and CO_2 (avoided fossil fuel usage) emission reductions of a typical 3-MW electricity generation project using LFG is about 34,700 metric tons of carbon equivalent per year, the environmental equivalent of the CO_2 emissions from nearly 296,000 barrels of oil consumed. The annual CH_4 and CO_2 emission reductions of a typical direct-use LFG energy project using 1,000 scf per minute (scfm)[2] of LFG is

[2] *Scfm is a volumetric measurement that indicates how many ft^3 of LFG pass a stationary point in 1 minute under standard conditions.*

nearly 32,300 metric tons of carbon equivalent per year, the environmental equivalent of the CO_2 emissions from more than 13.3 million gallons of gasoline consumed (U.S. EPA, 2011c).[3]

The Lanchester Landfill LFG energy project in Narvon, Pennsylvania, is a 3,800 scfm project that has annual avoided CO_2 emissions of 12,900 metric tons of carbon equivalents, due to the offset of fossil fuel usage. This reduction is equivalent to the carbon sequestered annually by 10,100 acres of pine or fir forests or the annual greenhouse emissions from 9,060 passenger vehicles (U.S. EPA, 2007f).

Denton, Texas, took advantage of LFG to improve its local air quality. In 2004 and 2005, air quality testing in Denton County reflected higher than acceptable levels of ozone concentrations. To reduce vehicle pollution from its fleet, the city established a public/private partnership to construct and operate a biodiesel production facility fueled by CH_4 gas from the city's landfill. For three years, the plant used the landfill CH_4 as a fuel source for biodiesel production. As a result, the city reduced its emissions of criteria air pollutants and met federal air quality standards by using alternative fuels for a portion of its fleet. The city began utilizing the LFG to generate electricity in 2008 (U.S. EPA, 2006; U.S. Conference of Mayors, 2007).

IMPLICATIONS FOR THE ENVIRONMENT

In addition to providing a continuous source of energy and improving local air quality, using LFG can significantly reduce GHG emissions. Since its inception, LMOP has helped 520 LFG energy projects in the United States reduce landfill CH_4 emissions and avoid CO_2 emissions by a combined 44 million metric tons of carbon equivalent (MMTCE). In 2010, reductions from all operational LFG energy projects were equivalent to:

- Carbon sequestered annually by 20.7 million acres of pine or fir forests; or
- Annual GHG emissions from 18.5 million passenger vehicles.

Source: U.S. EPA, 2011d.

- **Generate additional revenue.** Local governments can earn revenue from selling LFG directly to end users or into the pipeline, or from selling electricity generated from LFG to the grid. Depending on who owns the rights to the LFG and other factors, a local government might also generate revenue by selling renewable energy certificates (RECs), trading GHG emissions offsets, and providing other incentives.

An LFG energy project at Catawba County's Blackburn Landfill in Newton, North Carolina, is expected to earn nearly $7 million over the project's lifetime and will allow the county to keep its tipping fee constant for the next 10 years (U.S. EPA, 2005a).

JACKSON COUNTY GREEN ENERGY PARK

Jackson County, North Carolina, has developed a Green Energy Park that includes three professional blacksmith studios and a series of greenhouses, and provides artisans with free LFG to fuel kilns and other studio equipment. In addition to achieving energy and environmental benefits, the project supports local businesses and is expected to add more than 20 jobs to the local economy when fully operational.

Source: Jackson County, 2008.

- **Increase economic benefits through job creation and market development.** LFG energy project development can greatly benefit the local economy. For example, a typical 3-MW LFG electricity generation project can create more than 20 jobs within the state and local economies during its construction phase (U.S. EPA, 2010a). LFG energy projects, which involve engineers, construction firms, equipment vendors, utilities, and end users, also sustain certain jobs for each year the project operates. In addition, some materials and services are obtained from state and local economies. In some cases, new businesses (e.g., brick and ceramics plants, greenhouses, and craft studios) have located near a landfill to use the LFG for their work.
- **Demonstrate environmental leadership.** Using LFG, a green power source (see text box on page 1), can be an effective way for local governments to demonstrate environmental leadership and enhance community awareness of the benefits of clean energy development.

[3] Combusting captured CH_4 to generate electricity produces two byproducts: water and CO_2. The CO_2 that is emitted from LFG energy projects is not considered to contribute to global climate change because the carbon was contained in recently living biomass and would have been emitted through the natural decomposition process.

The EnergyXchange project in Burnsville, North Carolina, demonstrates community-level environmental stewardship. The project was initiated with an LFG collection system at the nearby Yancey-Mitchell Landfill. This action galvanized a community partner, Blue Ridge Resource Conservation & Development Council, to organize a Landfill Methane Task Force, which included more than 140 people from 40 agencies and organizations. The Task Force determined the end users for the LFG and identified operating partners and resources crucial to the project. EnergyXchange has become one of the nation's model LFG energy recovery projects and is used internationally as an example of a successful small LFG energy project (EnergyXchange, 2010). The environmental impact of the Yancey-Mitchell County Landfill Reuse Project is equivalent to the carbon sequestered annually by 950 acres of pine or fir forests or the annual greenhouse gas emissions from 850 passenger vehicles (U.S. EPA, 2011c).

- **Reduce environmental compliance costs.** Current EPA regulations under the Clean Air Act (CAA) require landfills with capacities greater than 2.5 million megagrams (Mg) of MSW and NMOC emissions of 50 Mg per year to capture and combust LFG to prevent NMOCs from contributing to smog formation and threatening air quality. LFG energy projects offer the opportunity to reduce the costs associated with regulatory compliance by turning pollution into a valuable renewable energy resource (U.S. EPA, 2011a).

In 1990, Glendale, California, was confronted with the challenge of complying with increasingly stringent environmental regulations governing the operation of power plants and landfills. The city reviewed its options, and implemented an LFG energy project to deliver LFG to a local generating station and use it as a base fuel along with natural gas or fuel oil. The composition of LFG offered the opportunity to further reduce emissions of nitrogen oxides (NO_X) during electric power generation. The city was able to simultaneously comply with the regulations, generate tangible environmental benefits, and lower costs for the consumer (Power Engineering, 1995).

- **Improve air quality.** Collecting LFG to produce energy improves the air quality of the surrounding community by reducing emissions of criteria pollutants and hazardous air pollutants (HAPs) and minimizing landfill odors. Capturing and utilizing LFG directly avoids emissions of NMOCs, components of untreated LFG that can contribute to smog formation. In addition, using LFG can indirectly avoid emissions of several criteria pollutants, including sulfur dioxide (SO_2, a major contributor to acid rain), particulate matter (a respiratory health concern), NO_X, and trace HAPs that would result from using fossil fuels in conventional energy generation (U.S. EPA, 2011a).[4] CH_4 captured from landfills can be used as an alternative fuel that burns cleaner than traditional fuels.

- **Conserve land.** LFG energy projects can enhance solid waste decomposition, increase landfill capacity, and mitigate the need to build new landfills or expand existing ones.

LaGrange, Georgia, has achieved gains of 15 to 30 percent in landfill capacity as a result of an LFG energy project initiated in 2001 (SGPB, 2008).

Riverview, Michigan, developed an LFG energy project on a 212-acre landfill owned by the city. The LFG is used to create electricity with two gas turbines. The local utility purchases the electricity under a 25-year power purchase agreement. Benefits to the community from the closed landfill include its use as a wintertime skiing and recreation area and a future golf practice facility (U.S. EPA, 2007g).

- **Create other benefits.** By linking communities with innovative ways to deal with their LFG, LFG energy projects offer increased environmental protection, better waste management, and responsible community planning, all of which are top priorities for local governments (U.S. EPA, 2011a).

4 LFG electricity generation systems, like all electricity generation combustion systems, generate some emissions of NO_X, a criteria pollutant that can contribute to local ozone and smog formation. Depending on the LFG energy project, the NO_X emission reductions from the power plant may not completely offset the NO_X emitted from the LFG electricity project (U.S. EPA, 2011a).

The CommunityTIES Project is an LFG development initiative that works with a cluster of counties in North Carolina to facilitate the development of community-based LFG energy projects which generate local economic development. The statewide project is managed by the Appalachian State University Energy Center with funding from the GoldenLEAF Foundation, the North Carolina State Energy Office, and the Z. Smith Reynolds Foundation (CommunityTIES Project, 2008).

LFG collection can also improve safety by reducing explosion hazards from gas accumulation in structures on or near the landfill (U.S. EPA, 2011a).

3. LANDFILL GAS ENERGY TECHNOLOGIES

A number of factors, including the availability of an energy market, project costs, potential revenue sources, and other technical considerations, can determine which technologies are most appropriate for a particular LFG energy project. Technologies for converting LFG into energy include:

- **Electricity generation.** Approximately 70 percent of the LFG energy projects currently in operation in the United States are used to generate electricity, for on-site use and/or to sell to the grid (U.S. EPA, 2011a). (For more information on using on-site renewable energy generation systems, see EPA's *On-Site Renewable Energy Generation* guide in the *Local Government Climate and Energy Strategy Series*.) Electricity from LFG can be generated using a variety of technologies, including internal combustion engines, gas turbines, and microturbines, with 85 percent of LFG electricity generation projects using internal combustion engines or turbines.[5] One million tons of landfilled MSW can produce an electricity generation capacity of 0.8 MW (U.S. EPA, 2009c).

[5] *Microturbine technology is sometimes used at smaller landfills and in highly specialized applications. Less common LFG electricity generation technologies include boiler/steam turbine applications in which LFG is combusted in a large boiler to generate steam, which is then used by the turbine to generate electricity; and combined cycle operations that combine a gas turbine, which combusts the LFG, and a steam turbine, which uses steam generated from the gas turbine's exhaust to create additional electricity (U.S. EPA 2009d).*

The Lancaster County Solid Waste Authority, in Pennsylvania, generates 3,200 kilowatts (kW) of electricity through a partnership with a local energy company, PPL Energy Services. The electricity is produced from two LFG-fired generators. For two years, boilers captured waste heat to provide steam to the nearby Turkey Hill Dairy, a well known maker of ice cream and dairy products (U.S. EPA, 2007e).

- **Direct use of LFG.** Direct use of LFG, which involves transmitting the medium-Btu gas via pipeline to be combusted by an end user, accounts for approximately 30 percent of all LFG energy projects in the United States (U.S. EPA, 2011a). LFG can be used by end users to fuel boilers, dryers, kilns, greenhouses, and other thermal applications. Current industries using LFG include automobile manufacturing, chemical production, food processing, pharmaceutical, cement and brick manufacturing, wastewater treatment, consumer electronics and products, and prisons and hospitals (U.S. EPA, 2009c). One million metric tons of landfilled MSW can produce between 8,000 and 10,000 pounds of steam per hour when LFG is used to fuel a boiler (U.S. EPA, 2009d). The economics of an LFG energy project improve the closer the landfill is to the end user. The piping distance from a landfill to its LFG end user is typically less than 10 miles, although piping LFG up to 20 miles can be economically feasible, depending on the amount of gas recovered at the landfill and the energy load of the end-use equipment (U.S. DOE, Undated).

- **Combined heat and power.** One specific type of LFG use is as a fuel source for combined heat and power (CHP) or cogeneration systems that generate both electricity and thermal energy. CHP systems can achieve substantially higher efficiencies than separate heat and power systems that do not use the waste heat produced in electricity generation. Thermal energy cogenerated by LFG energy projects can be used for on-site heating, cooling, and/or process needs, or piped to nearby industrial or commercial users to provide a second revenue stream for the project (U.S. EPA, 2009d).

CHP is often a better economic option for end users located near the landfill or for projects where the end user requires both electricity and waste heat. For more information on CHP, see EPA's *Combined Heat and Power* guide in the *Local Government Climate and Energy Strategy Series*.

In Antioch, Illinois, the local high school is purchasing electricity and by-product heat from a nearby privately owned LFG energy cogeneration project that uses 12 30-kW microturbines. Purchasing electricity and heat generated at the landfill saves the school nearly $100,000 annually in energy costs (RMT, 2008).

ADDITIONAL RESOURCES ON CHP APPLICATIONS

For additional information on CHP, see EPA's *Combined Heat and Power guide* in the *Local Government Climate and Energy Strategy Series* and EPA's *Combined Heat and Power Partnership* at **http://www.epa.gov/chp**.

- **Alternate fuels.** Production of alternate fuels from LFG is an emerging area and can involve several technologies, including:
  - ***Pipeline fuel.*** Municipalities can deliver LFG to the natural gas pipeline system as both a high- and medium-Btu fuel. Upgrading LFG to produce high-Btu gas involves separating CH_4 from the CO_2 component of LFG. The separated CH_4 can be sold to natural gas suppliers or used in applications requiring high-Btu fuel. Although expensive, newly developing technologies are reducing the cost of these types of projects, which are ideally suited for larger landfills located near natural gas pipelines.

In King County, Washington, the county is working with a project developer to produce pipeline quality natural gas from the LFG captured at the Cedar Hills Regional Landfill. The county expects to receive $1.3 million annually through a contract with a natural gas provider. Other benefits include an estimated annual avoidance of CO_2 emissions equivalent to the annual GHG emissions from 17,500 passenger vehicles (U.S. EPA, 2011c), and reduced GHG emissions of approximately 60 percent (King County, 2007; 2008).

  - ***Vehicle fuel.*** LFG can also be converted to vehicle fuel. Vehicle fuel applications involve using LFG to produce compressed natural gas (CNG), liquefied natural gas (LNG), or methanol. This process involves removing CO_2 and other trace impurities from LFG to produce a high-grade fuel that is at least 90 percent CH_4. Currently, CNG and LNG vehicles comprise a very small portion of automobiles in the United States, so there is not a significant demand for these vehicle fuels. However, with growing interest in alternative fuels, demand is expected to increase.

Waste Management, Inc. uses LFG from its Altamont Landfill in Livermore, California, to create LNG for use in garbage trucks (U.S. EPA, 2010b).

DENTON, TEXAS—BIOFUEL PROCESSING

LFG captured from the Denton, Texas, landfill was piped to a local biodiesel facility for three years where it was combusted to heat renewable feedstock to produce B20 biodiesel (20 percent biodiesel, 80 percent diesel) fuel for the city's vehicle fleet. The project was expected to reduce the fleet's emissions of criteria pollutants by 12 tons annually.

Source: U.S. EPA, 2006.

4. KEY PARTICIPANTS

A number of participants can play a key role in planning, designing, and implementing an LFG energy project, including:

- **Local government officials and staff.** Local officials often begin the process of implementing LFG energy projects. The mayor or county executive can play a key role in increasing public awareness of the benefits of LFG energy. Including LFG goals in a mayor's or county executive's priorities can lead to increased funding for LFG energy potential studies and/or projects. In other cases, LFG energy projects are often initiated by city and county councils and/or staff. Securing support from city or county council members can be important for ensuring that LFG initiatives receive the resources necessary to produce results.

Fairfax County, Virginia, developed a county-wide initiative that helped develop an LFG energy project. The I-95 Landfill's project includes nearly 200 extraction system wells that are used to collect LFG. The captured gas is used to generate 6 MW of electricity, enough for about 5,000 homes. The gas is also sent to the nearby Noman Cole Wastewater Treatment Plant, where it is used as a medium-Btu fuel in the sludge combustion process (MWCG, 2006; Fairfax County, 2007).

- **Developers.** While some local governments choose to self-develop LFG energy projects, many hire outside developers to finance, construct, own, and/or operate these projects. Developers are typically private companies that specialize in the various stages of building, owning, and operating LFG energy projects. In many instances, the local government retains ownership of the landfill while the developer assumes ownership of the LFG energy project.[6]

- **Regulatory and planning agencies.** LFG energy project owners prepare applications for zoning or land use permits, air permits, and conditional use permits. LFG energy project owners typically involve state environmental regulatory/permitting agencies, state energy agencies, and state public utility commissions early in the project planning process to ensure that all parties understand applicable environmental and land use requirements. In addition to state regulatory agencies, project owners often consult with county board members, local solid waste planning boards, and local zoning and planning departments. These partners are mainly involved during the permitting process of the facility. Project owners need to provide information showing that the project will meet emissions limits and other requirements, and will need to demonstrate compliance once the project becomes operational.[7]

- **Financial partners.** LFG energy project owners sometimes work with financial partners (e.g., tax creditors, bankers, and accountants) that provide financial assistance, prepare tax credit documentation, and track project finances. Tax creditors can assist LFG energy project owners in applying for federal, state, or local renewable energy tax credits. Bankers can help LFG energy project owners fund the LFG energy project, and accountants assist by tracking finances and revenues for the LFG energy project owner.

- **Professional partners.** LFG energy project owners often obtain legal, marketing, or technical services for an LFG energy project from a range of professional partners. For example, consulting engineers provide technical services and can assist in designing and constructing the project and keeping the project in regulatory compliance. Lawyers draw up and review contracts for multiple purposes, including protecting the LFG energy project owner from liability and establishing agreements between local governments and developers, end users, and other consultants or contractors. Lawyers might also review legal aspects of tax credits and project structures. Communications specialists or public information personnel can assist in fostering interaction with local residents, publicizing the environmental benefits of the LFG energy project, and preparing educational materials.

- **Contractors.** LFG energy project owners typically employ a variety of contractors to implement specific activities during the project planning, design, and implementation phases. Key types of contractors include:

  - ***Construction contractors*** building the facility;

  - ***Generator manufacturers*** providing project owners with manufacturing data on generator equipment to help them determine which type of generator best fits the design and operating requirements of the LFG energy project;

  - ***Generation plant operators*** operating and maintaining the facility, and providing energy output data, testing data, and maintenance information to the project owner;

  - ***LFG treatment system manufacturers*** providing LFG energy project owners with design and product specification assistance and working with the project owners, consultants, and end users to design, supply, and assemble the proper equipment to treat the LFG;

6 This guide uses the term "LFG energy project owner" to refer to either the local government or the developer it hires to construct and operate an LFG energy project.

7 Each state has different regulations and procedures for compliance and regulations. Some of these regulations can be found at: http://www.dsireusa.org.

- *Testing laboratories* working with LFG energy project owners to ensure that energy generation equipment does not emit higher levels than allowed by regulations and air permits; and
- *Wellfield operators* helping to ensure that the landfill is in compliance with local air permitting regulations, operating and maintaining the gas extraction wellfield, and making tuning adjustments necessary to collect the LFG.

- **Energy service companies.** LFG energy project owners sometimes work with energy service companies (ESCOs) that provide a comprehensive package of products and services to install, operate, and maintain LFG energy projects.

Little Rock, Arkansas, worked with an ESCO to construct an LFG energy project at the city's landfill. As part of the services package, the ESCO monitors and maintains the project and its pipelines. In addition, the ESCO helped the city reach an agreement with a local company to have a portion of the collected LFG piped to that company for use in a production facility (Little Rock, 2007).

- **End users.** LFG energy project owners often sell the energy generated by LFG energy projects to end users, including business and industrial customers, for direct use in boilers, heaters, kilns, furnaces, and other combustion equipment at their facilities. Project owners also sell electricity generated on-site by the LFG energy project to end users. Some end users can use LFG to produce their own electricity, as a feedstock for a chemical process, or for other purposes. In some instances, LFG energy project owners work with potential end users when developing projects to tailor the project to meet the end user's energy needs.

For the previously mentioned project in Little Rock, Arkansas, the city entered into an agreement with a local business to capture LFG from the city landfill and pipe it for direct use at the company's production facility. The city benefits from the LFG sale revenues, while the business benefits from below-market rate gas prices (Little Rock, 2007).

- **Utilities.** LFG energy project owners sometimes sell LFG, or the electricity it generates, to local utilities. Whether investor-owned or municipally owned, local utilities can use electricity generated from LFG energy projects to meet renewable portfolio standards that mandate specific percentages of renewable energy in a utility's supply.

In Denver, Colorado, the local government is partnering with the private corporation that manages the city-owned landfills to develop a 3.2-MW electricity generation plant that will supply electricity to the local utility (Denver, 2007).

- **Community partners.** When LFG energy project owners apply for permits, community members express questions, concerns, or opposition to the proposed facility during a public comment period. Depending on the public comment results, permits are issued, modified, or rejected. Local governments often work with landfill neighbors, local businesses, and environmental and community organizations to address any community concerns early in the project development stage. Local governments can work with the community to design a project that complies with community zoning and other ordinances, and provides environmental and economic benefits to the surrounding community.

The CommunityTIES Project emphasizes the importance of community groups in project development. While CommunityTIES provides technical, financial, and other support for local projects, the single most important success factor for its partner counties is building a team of local stakeholders to drive projects from conceptualization to end use operations. The CommunityTIES Project does not develop LFG energy projects so much as it develops the capabilities in local communities to develop their own projects. (CommunityTIES Project, 2008).

5. FOUNDATIONS FOR PROJECT DEVELOPMENT

Mechanisms that local governments have used to initiate LFG energy projects in their communities and promote the use of LFG as a renewable energy resource include:

- **Executive or city council initiatives.** Mayors, county executives, and city councils have been influential in initiating and promoting LFG energy projects in their communities, helping to sustain community support for LFG energy projects and ensure that projects receive sufficient funding.

The city council of Albuquerque, New Mexico, established a renewable energy initiative that included LFG energy as a priority. One of the city's recent projects consists of a 70-kW microturbine that captures the LFG and produces electricity (Albuquerque, 2008).

- **Renewable portfolio standards (RPS).** A number of local governments have adopted an RPS that requires municipally owned electric utilities to use a certain percentage of renewable energy in their overall energy supply.

The city council of Burbank, California, established an RPS requiring the Burbank Water and Power utility to use 20 percent renewable power by 2017. One component of the utility's strategy for meeting this goal is to use LFG captured at the local landfill, where two microturbine systems have been installed, with a total capacity of 550 kW (Burbank, 2006).

- **Commitments to purchase LFG from private landfill owners.** A number of local governments are purchasing LFG energy products from private landfill or LFG energy project owners. Some municipally owned utilities are purchasing green power from private landfill owners and selling it to commercial and residential customers.

In 2007, the city council in Anaheim, California, approved purchase agreements with two private LFG energy project owners to obtain 30 MW of LFG-based electricity capacity for its municipally owned utility, which has established a goal of increasing the amount of green power in its portfolio to 14 percent by 2010 (Anaheim, 2007).

For more information on purchasing green power products, see EPA's *Green Power Procurement* guide in the *Local Government Climate and Energy Strategy Series*.

6. STRATEGIES FOR EFFECTIVE PROJECT IMPLEMENTATION

Local governments can consider a number of approaches to help them overcome barriers to implementing LFG energy projects, including:

- **Evaluate site candidacy.** The first consideration for an LFG energy project owner is to determine whether the landfill is a candidate for LFG recovery. In general, strong candidate landfills should contain at least 1 million tons of waste, have an average depth of 50 feet or more, and be open or have closed within the last five years (these are general guidelines to which there are exceptions). After this initial screening, the project owner determines LFG recovery rates. EPA's Landfill Gas Emissions Model (LandGEM) can provide a more detailed analysis of LFG generation potential (available at: *http://www.epa.gov/ttn/catc/products.html#software*). The LFG energy project owner can also engage an engineering consulting firm to conduct a desktop feasibility study to assist with this task. In addition, LFG energy project owners can consider the distance between the landfill and anticipated end users. The piping distance from a landfill to a potential LFG end user is typically less than 10 miles, although piping LFG up to 20 miles can be economically feasible, depending on the amount of gas recovered at the landfill and the energy load of the end-use equipment (U.S. DOE, Undated).

- **Weigh the options of different technologies.** As mentioned in Section 3, *Landfill Gas Energy Technologies*, there are a number of different ways to convert LFG into energy. The best option for a particular landfill will depend on a variety of factors, including the availability of a market for energy, project costs, existence of a nearby end user, potential revenue sources, and other technical considerations. In general, the simplest and most cost-effective option is to sell medium-Btu gas to a nearby customer for direct use—this requires minimal processing and is tied to retail gas rates rather than utility buy-back rates. Power production and sale to a nearby utility can also be a cost-effective option if utility electricity buy-back rates are attractive. Other options, such as upgrading LFG to a high-Btu product for injection into a natural gas pipeline, entail higher capital and treatment costs and may only be cost-effective for those landfills with substantial recoverable gas.

- **Consider whether to engage a partner.** Some local governments have the expertise, resources, and desire to lead the project development effort on their own. However, in many cases, choosing the right development partner can greatly improve the likelihood of a project's success. From a local government's perspective, there are three ways to structure the development and ownership of an LFG energy project:

  - ***Develop the project internally, where the local government manages the development effort and maintains ownership control of the project;***

  - ***Team with a project developer who develops and builds the project;***

  - ***Team with a partner, where the local government works with an equipment vendor, an engineering/procurement/construction (EPC) firm, an industrial company, or a fuel company to develop the project and share the risks and financial returns.***

At the St. John's LFG energy project in Portland, Oregon, public and private entities worked together to pipe LFG from St. John's Landfill to a nearby lime plant for use as a primary fuel source for three lime kilns. Metro, a Portland regional planning authority, worked with Portland Landfill Gas Joint Venture Partners, which included a cement company and an investment banking firm, to develop the project (U.S. EPA, 2007h).

In Pennsylvania, the Clinton County Solid Waste Authority searched for a way to control the gas generated by the Wayne Township Landfill. Wayne Township teamed with a neighboring steel company to develop an LFG energy project and share both risks and financial returns. Through this partnership project, the Authority provides 970 scfm of LFG to the steel company to use as fuel in their furnace to reclaim railroad steel. This project has been a new source of revenue for the Authority and enabled the steel company to save on fuel costs (U.S. EPA, 2007i).

- **Retain or sell RECs.** RECs (also known as green tags, green energy certificates, or tradable renewable certificates) represent the environmental and other non-power attributes of electricity generated from renewable resources. They provide information about the generation resource (e.g., LFG), when the megawatt-hour (MWh) was generated, and the location of the generator. It is important to note though, that while some states define RECs to include the environmental and climate benefits associated with the CH_4 destruction, others do not. In the latter case, the environmental benefit is captured separately and can be sold as a carbon offset.

  When renewable energy is generated, the RECs may be separated from the physical electricity and sold as a distinct product. The REC buyer gains the contractual rights to make an environmental marketing claim and the physical electricity—that is sold separately—becomes "attributeless" or "null power" (i.e., environmentally equivalent to the regional power mix). In making a REC claim, the buyer permanently "retires" the REC and it can no longer be sold.

  There are two types of markets for RECs: compliance markets created by state-mandated RPS for retail electricity sales and a voluntary market driven by residential and business demand for zero emission electricity from renewable resources. Local governments can target the following purchasers of RECs from LFG energy projects: (1) electric service providers, for compliance with state RPS or to supply retail green power programs; (2) non-utility wholesalers and retailers, including REC marketers and REC brokers; and (3) retail customers (WRI, 2003; U.S. EPA, 2004).

In 2008 in Massachusetts, the state RPS required electric retailers to acquire RECs from qualified renewable energy generation projects (including LFG energy projects) to cover 3.5 percent of their 2008 sales. These RECs were sold to the retailers through the New England Power Pool General Information System (NEPOOL GIS) for more than 4¢ per kilowatt-hour (kWh), which made them an excellent revenue stream for qualifying renewable energy generation project owners (MCEC, Undated).

Local governments that sell the LFG energy they produce at their landfills sometimes choose to retain the RECs, allowing them to make an environmental marketing claim. For some local governments, keeping the RECs will help them meet the environmental goals they have established, such as reducing GHG emissions. Others want to simply say that the government is green-powered. Selling the RECs would transfer those rights to the REC buyer. For more information on RECs, see Section 3 in EPA's *Green Power Procurement* guide in the *Local Government Climate and Energy Strategy Series*.

- **Consider voluntary GHG markets.** Members of voluntary carbon markets look to purchase credits to offset their GHG emissions. LFG energy projects that capture and destroy or convert CH_4 can qualify as offset projects. The tons of CH_4 destroyed or converted can be traded on the market in terms of tons of carbon equivalent. For LFG energy projects to qualify as offsets in today's voluntary markets, the destruction of CH_4 must be additional, meaning that the local government collects the LFG voluntarily (as opposed to collecting LFG to comply with federal regulations, such as EPA's New Source Performance Standards, NSPS)[8]. In addition, most markets require that the installation of the LFG energy project be recent, although some buyers will accept offsets from LFG energy projects installed as early as 1999. Companies active in voluntary markets include CCX, EcoSecurities, Evolution Markets, Element Markets, AgCert, Blue Source, and GE/AES. Trading emissions offsets can provide a potentially significant source of income for small- and mid-sized LFG energy projects.

[8] *EPA promulgated the NSPS on March 12, 1996 under Title 1 of the CAA. The regulations target LFG emissions at larger landfills as it was determined these landfills produce the bulk of LFG emissions. The main purpose of the NSPS is to control NMOCs, which contribute to smog formation and contain trace carcinogens. For further information on these rules, see: http://www.epa.gov/ttn/atw/landfill/landflpg.html (U.S. EPA, 2008c).*

LANCASTER COUNTY LFG ENERGY PROJECT

The Lancaster County Solid Waste Management Authority has an LFG energy project that supplies power to a nearby utility. As a member of the Chicago Climate Exchange (CCX), the Authority made a legally binding commitment to reduce its GHG emissions by 6 percent by 2010, using 2006 as a baseline.

Source: U.S. EPA, 2007e.

- **Determine interconnection standards.** In some cases, local governments may want to connect an LFG energy project to the electricity grid. The availability of interconnection standards can be an important factor for determining the feasibility of an LFG energy project when there is excess energy supplied by the LFG energy project. A number of factors drive interconnect issues, including the amount of electricity the developer wants to interconnect, the sizing and capacity surrounding distribution, the location of distribution substations, interconnect procedures, and regulations and utility requirements.

In Prince George's County, Maryland, Brown Station Road Landfill sends LFG to the nearby Prince George's County Correctional Facility to generate steam and electricity. The county has an interconnection agreement with the local utility to pay $1,000 per month for the utility to meter and distribute the generated electricity to the grid. The county also generates income by selling the RECs generated by the project. Since the project's inception, the county has received an average of $60,000 per month for electrical generation, although revenues have been variable due to fluctuations in market costs (U.S. EPA, 2007a).

For additional information on interconnection standards, see Section 6 of EPA's *Combined Heat and Power* guide in the *Local Government Climate and Energy Strategy Series*.

- **Engage the community.** Many local governments have found that engaging the community can be a critical aspect of planning, constructing, and operating LFG energy projects. Community partners typically include neighbors of the landfill, the general public, local businesses, and environmental and community organizations. It is important to engage these partners early in the project development phase. LFG energy project owners can work with the community to address any concerns and to select a project that complies with community zoning and other ordinances and has environmental and economic benefits to the surrounding community.

- **Understand the community's role in permitting and compliance issues.** Unless there is significant opposition to an LFG energy project, community partners are mainly involved in the permitting process. When LFG energy project owners apply for required permits, such as air and zoning permits, community members can provide comments during the public comment period. For a detailed example on how to engage the community, see Section 9, *Case Studies: Yancey and Mitchell Counties, North Carolina—EnergyXchange Renewable Energy Center* on page 19.

The text box below provides a basic overview for local governments and other entities interested in developing an LFG energy project.

STEPS FOR DEVELOPING LFG ENERGY PROJECTS

1. **Estimate LFG recovery potential**. Strong candidates for LFG energy projects include landfills that: contain at least 1 million tons of MSW, have a depth of 50 feet or more, and are open or recently closed (U.S. EPA, 2009a). In addition, the site should receive more than 25 inches of precipitation annually (U.S. EPA, 2009a). EPA's LandGEM can provide a more detailed analysis of LFG generation potential (available at ***http://www.epa.gov/ttn/catc/products.html#software***).

2. **Evaluate project economics**. Local governments can evaluate the economic potential for converting LFG by using EPA's LFGcost-Web tool to help with preliminary economic evaluation, which includes public financing inputs (available to LMOP Partners at ***http://www.epa.gov/lmop/publications-tools/index.html#three***).

3. **Establish project structure**. Local governments can work with a developer or other partners. If a local government decides to work with partners, the terms of the partnership should be formalized in a contract that specifies which partner will own the gas rights and the rights to potential emissions reductions, and outlines partner responsibilities for design, installation, and operation and maintenance (O&M).

4. **Assess financing options**. Local governments can consider a number of financing options, including private equity financing, project finance, municipal bond financing, direct municipal funding, lease financing, and public debt financing through institutional or public stock offerings. For more information, see Section 7 *Costs and Financing Opportunities* on page 13.

5. **Negotiate energy sales contract**. Local governments can enter into contracts to sell LFG to end users. Negotiating sales contracts involves preparing a draft offer, 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.

6. **Secure permits and approvals**. The permitting process for an LFG energy project may require six to 18 months (or longer), depending on the project's location and recovery technology. LFG energy projects must comply with federal regulations relating to LFG emissions controls and control of air emissions from the energy conversion equipment. LMOP's State Resources page provides links to information regarding state specific regulations and permits. See: ***http://www.epa.gov/lmop/publications-tools/state-resources.html***.

7. **Contract for engineering, procurement, construction, and O&M**. Construction and operation of LFG energy projects are often best managed by firms with proven experience. Contractors can conduct engineering designs, site preparation, plant construction, and start-up testing.

8. **Install project and start up commercial operation**. The final phase of implementation is to start commercial operations and engage the community in educational outreach programs.

Source: U.S. EPA, 2009e.

7. COSTS AND FINANCING OPPORTUNITIES

This section provides information on the costs of evaluating, constructing, and installing LFG energy projects at local government-owned landfills and describes financing opportunities for addressing these costs.

Costs

In general, each LFG energy project involves project evaluation, purchase and installation of equipment (capital costs), and the expense of operating and maintaining the project (O&M costs). This section describes the costs involved in project evaluation, collection system and flaring, electricity generation, direct LFG use, and other LFG uses.

> **LFG ENERGY PROJECT COSTS**
>
> LMOP has developed LFGcost-Web, a tool to help with preliminary project economic evaluation. It is available at: ***http://www.epa.gov/lmop/publications-tools/index.html#three***.
>
> *Source: Smart Growth Network, 1998.*

- **Project evaluation costs.** The initial cost involved in implementing an LFG energy project involves conducting a feasibility study to determine project potential. A typical desktop feasibility study involves gas recovery modeling, pro forma financial analysis, site visits, and an evaluation of end-use options. Engineering consulting firms can perform these studies, with costs ranging from $10,000 to $15,000 per study. A more detailed study involving further gas analysis (including tests for CH_4, hydrogen sulfide, or siloxanes) may cost an additional $10,000.
- **Collection system and flaring costs.** Gas collection and flaring system equipment gathers LFG to be combusted for electricity generation or to be distributed for direct use, and provides a way to destroy the gas when the project is not operating. If a collection and flare system already exists, it can be treated as a "sunk cost,"[9] and the project cost only needs to consider necessary modifications to the system. The typical LFG collection and flare system costs approximately $24,000 per acre for installed capital costs, with annual O&M costs of approximately $4,100 per acre (U.S. EPA, 2009b).

> **CONSIDERATIONS FOR COLLECTION SYSTEM AND FLARING COSTS**
>
> Collection system and flaring costs can vary depending on design variables. Key factors that influence costs include:
>
> - **For gas collection wells or collectors:** depth of the waste and spacing of wells or collectors.
> - For gas piping: gas volume and length of piping.
> - For the condensate knockout drum: volume of the drum.
> - For the blower: blower size.
> - **For the flare:** flare type (enclosed or open, ground or elevated) and size.
>
> *Source: U.S. EPA, 2009b.*

- **Electricity generation project costs.** The most common technologies for converting LFG into electricity include internal combustion engines, gas turbines, microturbines, and small engines. Each technology is generally suited to a particular range in project capacity. Internal combustion engines, the most commonly used engines in LFG electricity generation projects, tend to be used for projects in the 800-kW to 3-MW capacity range, while gas turbines are typically used for projects that have capacities of 3 MW or more (U.S. EPA, 2009b). Microturbines and small internal engines are best suited for small projects in the 250-kW to 1-MW range or for projects with unique power needs (U.S. EPA, 2009b). Table 1 illustrates typical capital and O&M costs for different electricity project options.

[9] *Sunk costs are defined as costs that have been incurred and that cannot be recovered to any significant degree.*

TABLE 1 CAPITAL AND O&M COSTS OF LFG ELECTRICITY GENERATION PROJECTS

Technology	Optimal Project Size (capacity)	Typical Capital Costs ($/kW capacity)	Typical Annual O&M Costs ($/kW capacity)
Microturbine	≤ 1 MW	$5,500	$380
Small Internal Combustion Engine	≤ 1 MW	$2,300	$210
Internal Combustion Engine	≥800 kW	$1,700	$180
Gas Turbine	≥3 MW	$1,400	$130

Source: U.S. EPA, 2009b.

- **Direct-use project costs.** For direct-use LFG energy projects, costs vary depending on the end-user's requirements, but typically include expenses for the following components: gas compression and treatment systems to condition gas for end-user equipment, pipelines to transport LFG to the end user, and condensate management systems for removing condensate along the pipeline. Typical costs for gas compression and treatment are about $960 per scfm with O&M costs of $90 per scfm. For gas pipeline and condensate management systems, the typical capital costs are about $330,000 per mile with negligible O&M costs (U.S. EPA, 2009b).

  End users may need to modify their equipment to make it suitable for combusting LFG, but these costs are usually borne by the end user and are site-specific. However, modification costs are typically offset by cost savings as a result of purchasing energy at below-market rates.[10]

- **Other project type costs.** In addition to electricity generation and direct-use projects, there are other less common project options including CHP applications, leachate evaporation, vehicle fuel, and upgrade to high-Btu gas for sale to natural gas distribution companies. These technologies are not as universally applicable as the more traditional LFG energy projects; however, depending on the specific situation, they can be very cost-effective.

PLANNING FOR LFG ENERGY PROJECT SUCCESS

In successful projects, local governments keep detailed records, are conservative about the energy potential from the landfill, review all pro forma statements, and assist the procurement process in any way possible, to build public support and ensure sound and efficient financial transactions. These steps minimize permitting delays and enhance public support, which help increase the attractiveness of the project to investors.

Source: U.S. EPA, 2009b.

Financing

A combination of different financing options may be the best approach for funding an LFG energy project. Financing options available to LFG energy project owners include:

- **Municipal bond financing.** For municipally owned landfills or end users, the issuance of tax deferred bonds can be used to finance LFG energy projects. This is the most cost-effective method of financing a project since the interest rate is often 1 or 2 percent below commercial debt interest rates and can often be structured for long repayment periods (U.S. EPA, 2009b).

- **Direct municipal funding.** Often the lowest-cost financing available, direct municipal funding uses the local government operating budget to fund the LFG energy project, eliminating the need for outside financing or obtaining partners and delays caused from their project evaluation needs. However, municipalities may not have sufficient budgets to finance a project.

10 LMOP provides a boiler retrofit fact sheet to help end users understand the types of modifications required to use LFG in a boiler (see http://www.epa.gov/lmop/documents/pdfs/boilers.pdf).

Additionally, public approval may be required for LFG energy projects, which can increase the time required to complete a project.

Fargo, North Dakota, financed an LFG collection and flare system to reduce odors from landfill operations. A neighboring company that processes oilseed recognized the energy potential and approached the city about using LFG in their boilers. The city and the oilseed processor split the cost of the 1.5-mile pipeline, and the oilseed processor financed the installation of dual-fuel burners and the new control system. The city will recover its capital expense through the sale of LFG (U.S. EPA, 2007b).

- **Private equity financing.** This financing approach involves an investor who is willing to fund all or a portion of the project in return for a share of project ownership. Potential investors include developers, equipment vendors, gas suppliers, industrial companies, and often investment banks. For small projects without access to municipal bonds, private equity financing can be one of the better means of obtaining financing. This option typically has lower transaction costs and usually enables a local government to move faster on financing than with other options. However, private equity financing can be more expensive than other financing options. In addition, investors may expect to receive benefits from providing funding, such as service contracts or equipment sales, as well as a portion of the cash flow.

EPA'S LANDFILL METHANE OUTREACH PROGRAM FUNDING RESOURCES

LMOP has developed a comprehensive funding guide that provides information about a broad range of types of funding options available for LFG energy projects. The guide provides examples of successful funding approaches that can be replicated around the country to promote LFG energy. The types of funding covered in the guide include grants, loans, tax credits and exemptions, and production incentives. Information about state RPSs that include LFG as an eligible resource is also provided.

For further information, see ***http://www.epa.gov/lmop/publications-tools/funding-guide/index.html***.

Source: U.S. EPA, 2008b.

- **Project finance.** With this approach, often used for private power projects, lenders look to a project's projected revenues rather than the assets of the developer to ensure payment. The developer retains ownership control of the project while still obtaining financing. Typically, the best sources for obtaining project financing are from small investment capital companies, banks, law firms, or an energy investment fund. The main disadvantages of project finance are high transaction costs and the lender's high minimum investment threshold.

- **Lease financing.** For this approach, the project owner leases all or part of the LFG energy project assets. This arrangement usually allows the transfer of tax benefits or credits to an entity that can best make use of them. Lease arrangements can allow for the user to purchase the assets or extend the lease upon completion of the lease. The benefit of lease financing is that it frees up the project owner's capital funds, while allowing the owner to maintain control of the project. Disadvantages include complex accounting and liability issues, and the loss of tax benefits to the project owner.

- **Renewable energy trust funds.** Some local governments have been awarded grants to fund LFG energy projects through renewable energy trust funds administered by nonprofit organizations, state agencies, or other sources. The Renewable Energy Trust in Massachusetts is funded by a public benefits fund and administered by the Massachusetts Technology Collaborative.

The Renewable Energy Trust provided the town of Barnstable, Massachusetts, with a $20,000 grant to evaluate the feasibility of powering a new town facility with LFG captured from the town's landfill (MTC, 2005).

DATABASE OF STATE INCENTIVES FOR RENEWABLE ENERGY

The Database of State Incentives for Renewables & Efficiency (DSIRE) is another resource for funding and other incentives for LFG energy projects. For more information, see ***http://www.dsireusa.org/***.

- **Loans.** Local governments can obtain low-interest loans from federal or state agencies to finance LFG energy projects.

LaGrange, Georgia, used a $1 million low-interest loan from the Georgia Environmental Facilities Authority, under the agency's Solid Waste Loan Program, to upgrade its landfill management equipment and to install a gas collection facility at the landfill (U.S. EPA, 2008a).

- **Property and sales tax exemptions.** Exempting LFG energy projects from state taxes is another powerful incentive to encourage new projects. Some states have exempted equipment that generates energy from LFG from state sales and use taxes or from state property taxes.

Maryland's Clean Energy Incentive Tax Credit is an example of a program to provide tax credits to facilities that produce energy from biomass (including LFG). Qualifying facilities can claim a credit on their state income taxes (MEA, 2012).

8. FEDERAL, STATE, AND OTHER PROGRAM RESOURCES

A number of federal, state, and other programs can offer technical assistance and information resources to local governments.

Federal Programs

- **Global Methane Initiative.** The Global Methane Initiative represents a multi-nation commitment to reducing CH_4 emissions; as of November 2011, 40 individual member countries and the European Commission were members. The Initiative provides a framework for voluntarily reducing CH_4 emissions and using captured CH_4 as a clean energy source. The Initiative brings private and public sector partners together to find effective ways to protect the environment and meet energy needs.

  Web site: *http://www.globalmethane.org*

- **National Renewable Energy Laboratory (NREL).** NREL is the primary national laboratory for renewable energy and energy efficiency research and development. It provides local governments with information on existing and emerging technologies, including how to plan, site, and finance projects using renewable energy sources. NREL also provides information on developing rules and regulations for net metering and RPSs for municipal utilities.

  Web site: *http://www.nrel.gov/applying_technologies/state_local_activities/*

- **U.S. Department of Energy (DOE) Green Power Network.** Local governments can obtain news and information on green power markets from the DOE Green Power Network. The Network's Web site provides information on green power providers, green power products, and federal, state, and local policies pertaining to green power markets, and contains an extensive library of papers, articles, and reports on green power.

  Web site: *http://www.eere.energy.gov/greenpower/*

- **U.S. DOE State Office of Energy Efficiency and Renewable Energy (EERE) State Activities & Partnerships.** This partnership provides states with information on EERE-sponsored projects and EERE's cooperative projects and grants. It also provides state energy statistics, case studies and publications, and news about state energy projects.

  Web site: *http://apps1.eere.energy.gov/states/*

- **U.S. EPA Combined Heat and Power Partnership.** The CHP Partnership is a voluntary program seeking to reduce the environmental impact of power generation by promoting the use of CHP. The Partnership works closely with energy users, the CHP industry, state and local governments, and other clean energy stakeholders to facilitate the development of new projects and to promote their environmental and economic benefits.

  Web site: *http://www.epa.gov/chp/*

- **U.S. EPA Green Power Partnership.** The EPA Green Power Partnership is a voluntary climate protection program that creates demand for electricity produced from renewable energy sources. Local government partners earn publicity and recognition, and are ensured of the credibility of their green power purchases. In addition, partners can receive EPA advice for identifying green power products and information on purchasing strategies. EPA also provides tools and resources that offer information on green power providers and calculate the environmental benefits of green power purchases. Through the Green Power Communities initiative, the Partnership recognizes cities, towns, and villages where local governments and their businesses and residents collectively purchase quantities of green power that meet EPA-determined requirements. To get started, the community's local government first becomes an EPA Green Power Partner and takes the lead with EPA on beginning a local community campaign.

Web sites: *http://www.epa.gov/greenpower/* (Green Power Partnership)
http://www.epa.gov/greenpower/communities/index.htm (Green Power Communities)

- **U.S. EPA Landfill Methane Outreach Program.** LMOP is a voluntary assistance program that helps reduce GHGs from landfills by encouraging the recovery and use of LFG as an energy resource. LMOP forms partnerships with communities, local governments, utilities, power marketers, states, project developers, and nonprofit organizations to overcome barriers to project development by helping them assess project feasibility, find financing, and market the benefits of project development to the community. The program offers technical assistance, guidance materials, and software to assess a potential project's economic feasibility; assistance in creating partnerships and identifying financing; materials to help educate the community and the local media about the benefits of LFG energy; and networking opportunities with peers and LFG energy experts to enable communities to share challenges and successes. Section 10 *Additional Examples and Information Resources* on page 20, provides additional information about LMOP's services.

  Web site: *http://www.epa.gov/lmop*

- **U.S. EPA State and Local Climate and Energy Program.** This program assists state, local, and tribal governments in meeting their climate change and clean energy efforts by providing technical assistance, analytical tools, and outreach support. It includes two programs:

  - ***The Local Climate and Energy Program*** helps local and tribal governments meet multiple sustainability goals with cost–effective climate change mitigation and clean energy strategies. EPA provides local and tribal governments with peer exchange training opportunities and financial assistance along with planning, policy, technical, and analytical information that support reduction of greenhouse gas emissions.

  - ***The State Climate and Energy Program*** helps states develop policies and programs that can reduce greenhouse gas emissions, lower energy costs, improve air quality and public health, and help achieve economic development goals. EPA provides states with and advises them on proven, cost–effective best practices, peer exchange opportunities, and analytical tools.

  Web site: *http://www.epa.gov/statelocalclimate/*

State Programs

A number of states administer programs that provide assistance to local governments for planning, designing, and operating LFG energy projects. State assistance often includes financial incentives, such as low interest loans, grants, and tax incentives. Grants that can be applied to the purchase, construction, and installation of LFG systems are another incentive some states are using.

For more information on programs administered by specific states, see *http://www.epa.gov/lmop/partners/state.html*.

Other Programs

Other sources of information and technical assistance include:

- **Database of State Incentives for Renewables & Efficiency.** A project of the North Carolina Solar Center and the Interstate Renewable Energy Council, DSIRE provides information on federal, state, and local incentives for renewable energy and energy efficiency projects, including tax credits, loans, and grants. The database also provides information on state and local regulations pertaining to renewable energy purchases and on-site renewable energy generation, including overviews of state and local net metering rules, RPSs, and requirements for renewable energy use at public facilities.

Web site: *http://www.dsireusa.org/*

- **Green-e Renewable Energy Certification Program.** Developed by the Center for Resource Solutions, Green-e is a voluntary certification and verification program for wholesale, retail, and commercial electricity products, RECs, and utility green pricing programs. Green-e certifies about 100 retail and wholesale green power marketers across the country. In addition, Green-e sets consumer protection and environmental standards for energy-related products. Local governments can seek certification from Green-e as purchasers of certified renewable energy, for which Green-e provides a label that can be displayed in government facilities.

  Web site: *http://www.green-e.org/*

- **Interstate Renewable Energy Council (IREC).** IREC provides information and assistance to state and local governments for a number of renewable energy activities, including public education, procurement coordination, and adoption of uniform standards.

  Web site: *http://www.irecusa.org/*

- **Renewable Energy Policy Project.** The Renewable Energy Policy Project, created by the Center for Renewable Energy and Sustainable Technology, was developed to accelerate the deployment of renewable energy technologies and serves as a clearinghouse for information on renewable energy technologies and policies.

  Web site: *http://www.repp.org/index.html*

9. CASE STUDIES

The following case studies describe two comprehensive LFG utilization projects initiated by local governments. Each case study describes how the program was started, key program activities, and program benefits.

DeKalb County, Georgia—Seminole Road MSW Landfill

The DeKalb County Sanitation Division is capturing LFG from the Seminole Road Landfill to generate electricity and address environmental challenges. Initiated in 2006, this self-developed project became one of the first suppliers of green power for the local utility's new green energy program.

PROGRAM INITIATION

The county commissioners asked DeKalb County officials to develop a 3.2-MW LFG energy facility, meet all regulatory requirements, and make it a showcase for LFG utilization. Additionally, the officials were asked to complete the project on an accelerated schedule without a third-party developer. Solid waste officials responded to this challenge, met all criteria, and completed the project on schedule. Due to an innovative design, build, and operate procurement approach, the project was completed seven months after county commissioners approved construction (U.S. EPA, 2007c).

Profile: DeKalb County, Georgia

Area: 270 square miles

Population: 750,000

Structure: DeKalb County is governed by seven elected county commissioners who set policies and appropriate funding, and an elected chief executive officer who administers day-to-day county operations. Management of the Seminole Road Landfill falls under the auspices of the County Sanitation Division in the Department of Public Works.

Program Scope: The Sanitation Division manages a 3.2-MW LFG electricity generation system at the Seminole Road Landfill, which contains approximately 10 million tons of MSW. This system provides the local utility with more than 22 million kWh of green power annually.

Program Creation: County commissioners directed the Sanitation Division to request proposals.

Program Results: The LFG energy project produces approximately 22.5 million kWh annually. Environmental benefit of emission reductions equates to the annual GHG emissions from 2,800 passenger vehicles.

Source: U.S. EPA, 2007c

PROGRAM FEATURES

The LFG energy project at Seminole Road Landfill was self-developed without the assistance of a third-party developer and with seamless interface with the existing flare system and wellfield infrastructure. The project uses two reciprocating engines with a combined capacity of 3.2 MW to produce electricity from a stream of captured LFG that reaches approximately 1,100 scfm. Additional captured LFG is combusted in a flare. The stream of LFG is produced by approximately 10 million tons of MSW that have been collected since 1977.

The project includes a contract with a local utility through which the utility purchases green power produced from the captured LFG (22.5 million kWh annually for 10 years). The revenues from the green power sales will enable the county to recover the $5 million cost of the system in less than five years. The project raised $1.9 million in revenue between November 2007 and July 2008.

The showcase energy facility emphasizes education and offers tours about LFG utilization. The facility offers a screen where visitors can view real-time performance of the electricity generators, and displays a full circle mural that follows trash from its collection to the landfill to LFG generation, capture, and ultimately to providing electricity to the same residents and businesses from which the trash was collected (U.S. EPA, 2007c; 2007d).

PROGRAM RESULTS

In addition to providing a source of green power for the community (i.e., enough to power 2,000 homes annually), the program is expected to achieve annual avoided emissions reductions of approximately 4,000 metric tons of carbon equivalent. Annual emission reductions are equivalent to the annual GHG emissions from 2,800 passenger vehicles or CO_2 emissions from 34,200 barrels of oil consumed (U.S. EPA, 2007c).

Web site: ***http://www.epa.gov/lmop/projects-candidates/profiles/dekalbcountyandgeorgiapow.html***

Yancey and Mitchell Counties, North Carolina—EnergyXchange Renewable Energy Center

The EnergyXchange is a community-based organization in North Carolina that is currently utilizing LFG to provide energy to on-site glass blowing furnaces, a pottery kiln, and a greenhouse dedicated to preserving rare and native flora. The project is unique because it utilizes LFG from a landfill much smaller than what is typically considered to be commercially viable.

PROGRAM INITIATION

The project at EnergyXchange was initiated when an LFG collection system was activated at the nearby Yancey-Mitchell Landfill. This action galvanized a community partner, Blue Ridge Resource Conservation & Development Council, to organize a Landfill Methane Task Force including more than 140 people from 40 agencies and organizations. The Task Force determined the end uses for the LFG, identified operating partners, engaged local communities in the project, and identified resources crucial to project development (U.S. EPA, 2005b).

Profile: Yancey and Mitchell Counties, North Carolina

Area: Yancey County—313 square miles; Mitchell County—222 square miles

Population: Yancey County—18,000; Mitchell County—16,000

Structure: Each county is governed by a board of elected commissioners. In both counties, these boards select a county manager to direct day-to-day operations.

Program Scope: The EnergyXchange Renewable Energy Center was first developed adjacent to the Yancey-Mitchell Landfill.

Program Creation: An LFG collection system developed at the Yancey-Mitchell Landfill led to the creation of a task force to evaluate opportunities to use the captured LFG. The EnergyXchange project was initiated in 1999.

Program Results: Artisans at the EnergyXchange facilities have saved more than $1 million in energy costs compared to purchasing energy from conventional sources. The environmental benefits of the project are equivalent to the annual GHG emissions from 800 passenger vehicles.

Source: U.S. EPA, 2005b.

PROGRAM FEATURES

The EnergyXchange complex, which includes two craft studios, four greenhouses, three cold frames, a public gallery, and a visitor center, is located adjacent to a six-acre landfill and draws on the energy of a 37.5 scfm LFG flow. Water heated by LFG provides heat for a greenhouse where students learn how to propagate critical components of local ecosystems. Glass blowers fine tune their craft over flames fueled by LFG, and potters fire their wares in an oversized kiln, also fueled by LFG. In the visitor's center, citizens learn how LFG energy projects save money and help the environment. The project showcases community collaboration: in addition to the Blue Ridge Resource Conservation & Development Council, other partners include HandMade in America and Mayland Community College (EnergyXchange, 2011).

PROGRAM RESULTS

The efforts of EnergyXchange have demonstrated that LFG energy projects at small landfills can be beneficial and have shown the power of community partnerships. The savings to the artisans thus far exceeds $1 million compared to what they would have paid for traditional fuel sources. Artisans pay a nominal studio fee to receive an ample gas supply that is expected to power them for 15 years (U.S. EPA, 2005b).

The project's environmental benefits include annual GHG reductions of 1,200 metric tons of carbon equivalent, which is equal to the carbon sequestered annually by 900 acres of pine or fir forests, the annual GHG emissions of 800 passenger vehicles, or the CO_2 emissions from 10,300 barrels of oil consumed. Annual energy savings equate to heating 130 homes (U.S. EPA, 2005b).

Web site: *http://www.epa.gov/lmop/projects-candidates/profiles/energyxchangerenewableene.html*

10. ADDITIONAL EXAMPLES AND INFORMATION RESOURCES

Title/Description	Web Site
Examples of Landfill Gas Energy Projects	
Albuquerque, New Mexico. At the city's Los Angeles Landfill, LFG is captured and used to fuel an electricity-generating microturbine. The electricity is used to power the CH_4 extraction system and a groundwater treatment system. The remaining electricity is sold to the utility, as permitted by state interconnection and net metering rules.	*http://www.cabq.gov/envhealth/landfill.html*
Anaheim, California. In 2007, the Anaheim City Council approved agreements between the Anaheim Public Utilities and private owners of LFG energy projects to obtain 30 MW of LFG-generated electric capacity.	*http://www.anaheim.net/utilities/news/article.asp?id=824*
Antioch, Illinois. At 180 scfm, LFG is pumped from the adjacent H.O.D. Landfill (a former Superfund site) to 12 Capstone microturbines to provide heat and power to the high school in Antioch, Illinois.	*http://www.epa.gov/lmop/projects-candidates/profiles/antiochcommunityhighschoo.html*
BMW Manufacturing LFG. At its South Carolina assembly plant, BMW uses gas from Waste Management's Palmetto Landfill to fuel two gas turbine cogeneration units (total of 11 MW capacity) and recover 61 million Btu per hour of waste heat. BMW also uses an additional 800 scfm of LFG in paint shop oven burners and for indirect heating of the shop.	*http://www.epa.gov/lmop/projects-candidates/profiles/bmwmanufacturinglandfillg.html*
Chester County, Pennsylvania. In this innovative direct-use project, the Chester County Solid Waste Authority's Lanchester Landfill was the first in Pennsylvania to serve multiple customers. The 13-mile pipeline serves several industrial customers, including Dart Container Corporation, Advanced Food Products, and L&S Sweeteners.	*http://www.epa.gov/lmop/projects-candidates/profiles/lanchesterlandfillgasener.html*

Title/Description	Web Site
Dairyland Power. This electric cooperative in Wisconsin teamed up with Ameresco to implement a 3-MW LFG energy project at the Veolia ES Seven Mile Creek Landfill 2. Dairyland later added an additional engine to this project, as well as developed 10.4 MW of capacity at two other new projects.	*http://www.epa.gov/lmop/projects-candidates/profiles/dairylandlfgenergyproject.html*
DeKalb County, Georgia. Solid waste officials in this Georgia county self-developed a 3.2-MW project utilizing LFG generated from the nearby Seminole Road Landfill. This was the first green power project for Georgia Power.	*http://www.epa.gov/lmop/projects-candidates/profiles/dekalbcountyandgeorgiapow.html*
East Kentucky Power Co-op Green Power Program. The Bavarian Landfill located in Boone County, Kentucky went from a passive LFG system to an active system producing 3.2 MW of power in one year. The East Kentucky Power Cooperative (EKPC) initiated, developed, and financed the project at a cost of $4 million, from which the cooperative expects a 10-year payback.	*http://www.epa.gov/lmop/projects-candidates/profiles/eastkentuckypowercoopgree.html*
County of Fairfax, Virginia. In this self-developed project, LFG from the I-95 Landfill provides LFG to the nearby Noman Cole Wastewater Treatment Plant.	*http://www.fairfaxcounty.gov/dpwes/trash/dispmethrvc.htm* *http://www.epa.gov/lmop/projects-candidates/profiles/i95landfillwwtpproject.html*
Fargo, North Dakota. To help solve an odor problem, the city installed an LFG collection and flare system. Cargill, Inc., the landfill's neighbor that processes oilseed, recognized the energy potential and approached the city about using LFG in their boilers. The partners collaborated to develop a direct-use LFG energy project, showing the success that can come from public-private collaboration.	*http://www.epa.gov/lmop/projects-candidates/profiles/cityoffargoandcargilllfge.html*
Jackson County, North Carolina. Jackson County has created an energy park that includes three professional blacksmith studios and a series of greenhouses – all of which use LFG from the county landfill as a fuel.	*http://www.epa.gov/lmop/projects-candidates/profiles/jacksoncountyncgreenenerg.html*
Jefferson Parish, Louisiana. The Jefferson Parish Landfill provides 1,180 scfm of LFG to nearby Cornerstone Chemical Company. The LFG is provided via a 4.2-mile pipeline, which connects the landfill to the company's facility.	*http://www.epa.gov/lmop/projects-candidates/profiles/jeffersonparishandcytecin.html*
Johnson City, Tennessee. An LFG energy project at the 3.5 million ton MSW landfill in Johnson City collects 1,500 scfm and distributes nearly high-Btu LFG to be used as fuel for a boiler and reciprocating engine, providing steam, power, and chilled water to a veterans administration hospital, several university buildings, and a local civic center.	*http://www.epa.gov/lmop/projects-candidates/profiles/irisglenlandfillgasenergy.html* *http://www.epa.gov/lmop/documents/pdfs/conf/11th/bollinger.pdf*
Little Rock, Arkansas. Little Rock partnered with an ESCO to have an LFG energy project installed at the city's landfill. The ESCO helped the city negotiate a purchase agreement with a local manufacturer for a specified quantity of LFG.	*http://www.johnsoncontrols.com/publish/etc/medialib/jci/be/case_studies.Par.55152.File.dat/City%20of%20Little%20Rock%20PP.pdf*
Orange County, Florida. The Orange County Solid Waste Department worked with several contractors to develop an LFG energy project in 1998 at the county landfill. The county entered into a 20-year contract through which a private company would own and operate the facility. The county earned $5 million in the sale of the LFG energy project, and receives $400,000 annually for the rights to the LFG.	*http://www.epa.gov/lmop/projects-candidates/profiles/orangecountyfloridaandorl.html*
Palo Alto, California. Palo Alto, in an effort to secure larger quantities of green power for its own facilities and for its residents, worked with the local utility to have a third-party develop a 3.18-MW LFG energy project at a landfill owned by Santa Cruz County. In addition, the regional Water Quality Control plant uses LFG from the city's Palo Alto Landfill to process wastewater, saving $250,000 annually on energy costs compared to purchasing the energy from the grid.	*http://www.epa.gov/lmop/projects-candidates/profiles/oxmountainlandfillgaselec.html* *http://www.epa.gov/lmop/projects-candidates/profiles/alamedamunicipalpowerandp.html*

Title/Description	Web Site
Prince George's County, Maryland. The NASA Goddard Space Flight Center became the first federal facility to burn LFG to meet energy needs. LFG provides 100 percent of the facility's heating needs 95 percent of the time. The project includes a 5.5-mile pipeline that provides 1,070 scfm of LFG from the county-owned Sandy Hill Landfill to NASA.	*http://www.epa.gov/lmop/projects-candidates/profiles/nasagoddardspaceflightcen.html*
Prince George's County, Maryland. The Brown Station Road Landfill in Maryland has been sending LFG to the nearby Prince George's County Correctional Facility to generate electricity and steam since 1987. The county also sells green power to the local utility for sale on the grid.	*http://www.epa.gov/lmop/projects-candidates/profiles/brownstationroadonsiteele.html*
Wayne Township—Jersey Shore Steel. In this direct-use partnership, the Clinton County Solid Waste Authority in Pennsylvania provides 700 scfm of LFG to the Jersey Shore Steel Company to use as fuel in their furnace to reclaim railroad steel. This project was a new source of revenue for the Authority.	*http://www.epa.gov/lmop/projects-candidates/profiles/waynetownshiplandfillgase.html*
Wichita, Kansas. The Abengoa Bioenergy Corporation is using LFG from a Wichita landfill to fuel a boiler to produce ethanol.	*http://www.epa.gov/lmop/projects-candidates/profiles/abengoabioenergycorporati.html*
Yancey County, North Carolina. The EnergyXchange Renewable Energy Center is a community-based organization in North Carolina established to demonstrate the reasponsible use of LFG as an energy source, serve artisans, and meet local energy needs. The six-acre landfill provides 37.5 scfm of LFG to power nearby glass blowing furnaces, a greenhouse, and pottery kiln.	*http://www.epa.gov/lmop/projects-candidates/profiles/energyxchangerenewableene.html*
Zeeland Farm Soya. Zeeland Farm Soya, a soybean processing facility based in Michigan, receives LFG from Autumn Hills Recycling and Disposal Facility for use in a boiler.	*http://www.epa.gov/lmop/projects-candidates/profiles/zeelandfarmsoyalfgenergyb.html*
Information Resources on Landfill Gas Energy	
Adapting Boilers to Utilize Landfill Gas: An Environmentally and Economically Beneficial Opportunity. Using LFG in a boiler to create power is a common practice that requires minor technical adjustments to the boiler. This fact sheet details the retrofits needed to enable a boiler to operate efficiently using LFG.	*http://www.epa.gov/lmop/documents/pdfs/boilers.pdf*
Community Outreach. LMOP provides a brochure on how to engage the community in LFG energy projects.	*http://www.epa.gov/lmop/documents/pdfs/new_community_brochure.pdf*
Feasibility of Implementing LFG Energy. This feasibility study was conducted for the town of Barnstable, Massachusetts. The town was evaluating the potential for an LFG energy project to supply electricity to two schools and a Public Works Department facility.	*http://www.masstech.org/Project%20Deliverables/GB_Barnstable_DPW_Final_Report.pdf*
Funding LFG Energy Projects: State, Federal, and Foundation Resources. This funding guide offers detailed information on innovative state, federal, and foundation funding resources available for LFG energy projects.	*http://www.epa.gov/lmop/publications-tools/funding-guide/index.html*
Garbage In, Energy Out—Landfill Gas Opportunities for CHP Projects. This article provides an overview of the benefits of and potential for using LFG in CHP applications.	*http://www.cospp.com/display_article/307885/122/CRTIS/none/none/Garbage-in,-energy-out---landfill-gas-opportunities-for-CHP-projects/*
Jackson County Green Energy Park. These presentations provide an overview of the Jackson County, North Carolina Green Energy Park's objectives and progress.	*http://www.epa.gov/lmop/documents/pdfs/conf/10th/Muth.pdf* *http://www.epa.gov/lmop/documents/pdfs/conf/13th/muth.pdf*

Title/Description	Web Site
Landfill Gas as a Fuel for Combined Heat and Power. This article provides information on how LFG energy projects can be used in CHP applications.	*http://www.energyvortex.com/files/Landfill_Gas_as_Fuel_for_Combined_Heat_and_Power.pdf*
Landfill Gas Data. The Energy Information Administration tracks data on LFG production and usage in the United States.	*http://www.eia.doe.gov/cneaf/solar.renewables/page/landfillgas/landfillgas.html*
Landfill Gas Energy. This fact sheet outlines the link between LFG energy and sustainable environmental development.	*http://www.epa.gov/lmop/documents/pdfs/LMOPGeneral.pdf*
Landfill Gas to Fuel. This Southern Legislative Conference paper provides an overview of LFG activities in southern states, including existing projects and state financial and technical assistance.	*http://www.csg.org/pubs/Documents/0801-Landfill_Gas_to_Fuel.pdf*
Landfill Gas Use Trends in the United States. This article discusses evolving trends in LFG use in the United States. The article provides information on market drivers that are motivating interest in LFG energy projects.	*http://www.jgpress.com/archives/_free/001417.html*
Landfill Macroeconomics: Taking the Big Picture. This article describes recent trends in MSW disposal which has seen a decline in growth. The article examines the consequences of this slowing growth in MSW disposal for solid waste management.	*http://www.mswmanagement.com/november-december-2006/landfill-macroeconomics-taking.aspx*
Landfill Methane Emissions Offsets. This CCX Web site provides information on how LFG energy projects can produce financial benefits through voluntary emissions trading markets.	*http://www.chicagoclimatex.com/news/publications/pdf/CCX_Landfill_Methane_Offsets.pdf*
Landfill Methane Recovery and Use Opportunities. This fact sheet provides information on opportunities for LFG energy projects to participate in the Global Methane Initiative.	*http://www.globalmethane.org/documents/landfill_fs_eng.pdf*
LMOP LFG Energy Project Profiles. LMOP has collected information on a number of LFG energy projects.	*http://www.epa.gov/lmop/projects-candidates/profiles.html*
LMOP Marketing & Communications Toolkit. This toolkit includes tips on communicating the benefits of LFG energy projects and promoting LMOP participation for states and local governments.	*http://www.epa.gov/lmop/partners/toolkit/index.html*
LMOP Partners and Endorsers. LMOP provides information about its Partners and Endorsers.	*http://www.epa.gov/lmop/partners/index.html*
LMOP Publications. LMOP provides many technical documents, fact sheets, and brochures on LMOP's Publications/Tools page.	*http://www.epa.gov/lmop/publications-tools/index.html*
Map of Current Energy Projects and Candidate Landfills. This map is a good indicator of the successful use of LFG as an energy resource and the historical and potential growth of LFG energy projects in the United States.	*http://www.epa.gov/lmop/projects-candidates/index.html*
An Overview of Landfill Gas Energy in the United States. This LMOP presentation provides information on the deployment of LFG energy projects around the country, as well as the benefits of LFG energy in general.	*http://www.epa.gov/lmop/documents/pdfs/overview.pdf*
Solid Waste Disposal Trends. This article provides an overview of trends in solid waste disposal, including LFG recovery projects.	*http://wasteage.com/mag/waste_solid_waste_disposal/*
State Resources. LMOP lists key state organizations to help those searching for state-specific information regarding permits and policies that may affect LFG energy projects.	*http://www.epa.gov/lmop/publications-tools/state-resources.html*

Title/Description	Web Site
State Partner Program Guide. This guide provides detailed information about the roles and responsibilities of State Partners and the support provided by LMOP.	*http://www.epa.gov/lmop/documents/pdfs/state_partners.pdf*
LFG Energy Project Development Handbook. This handbook provides LFG energy project development guidance. The intended audience for this handbook is landfill owners, energy service providers, corporate energy end users, state agencies, local governments, and communities.	*http://www.epa.gov/lmop/publications-tools/handbook.html*
Information Resources on Landfill Gas Energy	
LFGcost-Web—Landfill Gas Energy Cost Model. This tool can be used to evaluate the economic feasibility of an LFG enregy project and is available to LMOP Partners and Endorsers.	*http://www.epa.gov/lmop/publications-tools/index.html*
LFG Energy Benefits Calculator. This LMOP tool can be used to estimate GHG emission reductions from LFG energy projects.	*http://www.epa.gov/lmop/projects-candidates/lfge-calculator.html*
Landfill Gas Emissions Model. This model helps estimate emissions rates from MSW landfills and can be used to estimate total LFG and CH_4 generation from a project.	*http://www.epa.gov/ttn/catc/products.html#software*
LMOP Interactive Conversion Tool. This tool can be used to convert LFG-related statistics (e.g., cubic feet per minute to standard cubic feet per day), and to estimate LFG energy potential from an MSW landfill.	*http://www.epa.gov/lmop/projects-candidates/interactive.html*

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