

Landfill Gas as Fuel for Combined Heat and Power

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ABSTRACT

When landfill gas (LFG) is used in combined heat and power (CHP) systems, the benefits multiply. A CHP project powered by LFG not only provides significantly better energy efficiency and cost savings, but it also achieves significant environmental benefits from using a locally produced, biomass fuel.

The U.S. Environmental Protection Agency (EPA), Landfill Methane Outreach Program (LMOP) has supported the development of LFG energy (LFGE) projects for more than a decade. The LMOP encourages the development of LFGE projects in several ways. To achieve more LFG use, the program maintains voluntary partnerships with businesses, communities, and states. The LMOP provides information about LFGE opportunities in the United States and prepares preliminary feasibility studies for landfills and potential LFG users. The LMOP and the LFGE industry have achieved significant reductions in emissions of greenhouse gases, because LFG is approximately 50% methane and methane traps more heat in the atmosphere than carbon dioxide, the most prevalent greenhouse gas. The collection and use of each ton of LFG methane is equivalent to the reduction of over 20 tons of carbon dioxide emissions.

The LMOP maintains a landfill and LFGE project database (LMOP database), which classifies 16 LFGE projects as CHP. These projects range from a 120 kilowatt (kW) microturbine installation to a 12 megawatt (MW) cogeneration plant

CHP LFGE projects can create additional environmental benefits by offsetting fossil-fuel-based electricity and steam or heating demands

with a renewable fuel. In 2007, the existing CHP projects fueled by LFG will result in greenhouse gas reductions equivalent to preventing the use of approximately 1.3 million barrels of oil.

In addition, using the waste heat from LFG-fired generators in a CHP configuration can improve project financial results by as much as 100%, increasing the feasibility of developing LFGE projects. LMOP offers real-world project experience and tools to overcome the barriers in CHP LFGE project development.

INTRODUCTION

The Landfill Methane Outreach Program (LMOP) is a voluntary program of the U.S. Environmental Protection Agency (EPA), which encourages the use of landfill gas (LFG) for fuel in generators, boilers, combined heat and power (CHP), and other facilities. More than 425 LFG gas energy (LFGE) projects are operating in the United States today, and LMOP estimates that as many as 570 additional landfills could support future energy projects. CHP LFGE projects co-generate both electricity and thermal energy, usually using waste engine heat to produce steam or hot water. LFG cogeneration projects have been installed at industrial operations, using turbine or spark ignited (SI) reciprocating engine generators. The efficiency gains of capturing the thermal energy in addition to generating electricity can make CHP LFGE projects particularly attractive.

Landfill Gas

Landfills are the largest source of human caused methane emissions in the United States [1]. LFG contains approximately 50% methane, a potent greenhouse gas, and has a heat content approximately half the value of natural gas, i.e., 500 British thermal units per standard cubic foot (Btu/scf) vs. 1,000 Btu/scf. It is a natural by-product of the anaerobic decomposition of municipal solid waste (MSW) and, if uncontrolled, can contribute to smog and global warming and cause health and safety concerns.

LFG is generated 24 hours per day, 7 days per week. It is extracted from landfills using a series of wells and a blower (or vacuum) system. This system directs the collected gas to a central point. From this point, the gas can be destroyed by a flare or used to generate electricity, replace

fossil fuels in industrial and manufacturing operations, fuel greenhouse operations, or be upgraded to pipeline-quality gas. As a rule of thumb, about 432,000 cubic feet per day of LFG is produced from every 1 million tons of MSW placed in a landfill, which can produce about 0.8 MW of electricity.

The annual environmental benefit of producing each MW of LFG energy is equivalent to:

- planting approximately 10,500 acres of forest per year, or
- removing the emissions of approximately 7,300 vehicles per year, or
- preventing the use of approximately 89,000 barrels of oil per year.

CHP IN THE U.S. LFGE INDUSTRY

CHP is a proven, highly efficient alternative to separate power and heat production. It is the simultaneous production and usage of at least two forms of usable energy from the combustion of one fuel. CHP LFGE projects will produce electricity as well as shaft power, hot water, steam, chilled water, or dehumidification [2].

The U.S. EPA implements several voluntary partnership programs, including LMOP and the CHP partnership to reduce the environmental impact of power generation. In the past 6 years, the CHP partnership has helped CHP partners put more than 250 projects into operation. These CHP partnership-assisted projects contribute more than 3,570 MW of electric capacity [3].

The LMOP Database tracks 425 operational LFGE projects in the United States and 70% of these projects generate electricity, with an electric capacity of more than 1,200 MW. In 2006, the electricity generating LFGE projects produced 10 billion kilowatt-hours (kWh). Another 75 billion cubic feet of LFG was delivered as fuel for boilers or direct use applications. LFGE projects have online reliability over 90% [4].

The LMOP Database shows that there are 16 CHP LFGE projects currently operating in the United States, and the projects range in size from 120 kW to 12 MW. Sixty percent of the existing CHP LFGE projects use spark-ignition (SI) engines. These projects are located in 9 states and

have a combined capacity of 55 MW. In addition, three of the 25 LFGE projects under construction in 2007 are CHP [5].

CHP LFGE CASE STUDIES

CHP projects large and small have received recognition for their efficient use of LFG, a renewable fuel source. LMOP features profiles on CHP technologies and other project types on its web site, and LMOP and others have presented awards to the four CHP LFGE projects described below.

Modern Landfill, Inc., New York

The LFG-fired cogeneration facility at Modern Landfill in New York provides 100% of the electrical and heating requirements for H₂Gro Hydroponic Greenhouses, with excess electricity sold to the grid. LMOP partner innovative energy systems started the initial phase of this CHP LFGE project in 2001, when it designed and installed a 5.6 MW project powering and heating a half-acre greenhouse test plot. In its first year, the project yielded 180,000 pounds of tomatoes. After a successful test plot, this greenhouse was expanded to 7.5 acres and 12 MW of generating capacity. Today this H₂Gro facility produces over 3.5 million pounds of tomatoes per year. Innovative energy systems has received multiple awards for the project, which provides the community with employment and a new year-round exportable crop [5,6].

Creswell and Frey Farm Landfills, Pennsylvania

LMOP partners Lancaster County Solid Waste Management Authority, PPL Corporation, and Turkey Hill Dairy, formed a unique partnership to achieve a CHP LFGE project using gas from two different landfills in Lancaster County, Pennsylvania. The LFG is sold to PPL Energy Services, who operates two Caterpillar 3520 engines to produce 3.2 MW of electricity. The engine heat is captured to generate steam, which is sold to the nearby Turkey Hill Dairy through a closed-loop steam pipeline. The dairy has met 80% of its steam demands using LFG and offsets the use of 225,000 gallons of diesel fuel per year [6,7].

Burlington County Landfill, New Jersey

Smaller CHP LFGE projects sized from 120 kW to 2 MW have been successfully implemented at schools, hospitals, and recreation centers.

Since 2002, LFG from the Burlington County Landfill in Mansfield, New Jersey, has fueled four 30-kW Capstone microturbines installed outside the Rutgers University EcoComplex. These microturbines provide electricity for growing lights and fans at the research and development facility, and the waste heat is recovered and used to maintain required temperatures in the building [5,6].

H.O.D. Landfill, Illinois

A high school in Antioch, Illinois is meeting 100% of its building heating and electricity needs using LFG. This CHP LFGE project collects gas from the adjacent H.O.D. Landfill to fuel twelve 30-kW Capstone microturbines. The school estimates an annual fuel savings of \$100,000, and this project achieves annual reductions in greenhouse gases equivalent to preventing the use of over 36,000 barrels of oil. Additional electricity that cannot be used at the school is sold to the Commonwealth Edison Company [5,6].

BENEFITS OF CHP LFGE

Projects that reclaim heat from LFG-fueled engine-generators provide the typical benefits of CHP projects. Fuel use efficiency is improved, emissions are reduced, and fuel and operating costs decrease. CHP can provide industrial and commercial facilities with greater reliability and increased process flexibility than conventional generation methods. Because cogeneration technology is proven, CHP projects represent low technology risk.

Turbines and SI engines using LFG have similar heat conversion efficiencies as small natural gas generators and are approximately 28-33% efficient. In comparison, SI engines with CHP systems have been found to have an effective energy efficiency of 69-84% [8].

To evaluate the financial benefit of LFG-fueled CHP projects compared with standard electric generation projects, LMOP applied its preliminary feasibility tool, the Landfill Gas Energy Cost Model (LFGcost) to two LFGE projects—straight electricity generation with a standard 3 MW SI engine and a CHP project based on a similar engine generator.

LFG cost estimates based on typical project designs and for typical landfill situations. The model attempts to include all equipment, site work, permits, operating activities, and maintenance that would normally be

required for constructing and operating the project. LMOP default input parameters were used in this comparison to model project development by a private entity (i.e., industrial end-user or a third party developer) who would finance 80% of the project capital costs at an 8% interest rate over a 10-year period. The initial year product prices listed in Table 1 reflect the current LFGcost model default prices for electricity, LFG production, and waste heat and are escalated annually at a rate of 2%.

The LFGcost comparison assumed a 4-mile pipeline between the landfill and thermal host. In addition, the waste heat application was assumed to be one-tenth of a mile from the engine. It also assumed that both projects operate year-round.

LMOP also compared the environmental benefit of displacing conventional electricity generation, and for the CHP project, the additional displacement of a natural-gas-fired thermal energy demand. The greenhouse gas reduction benefits were calculated in units of metric tons of emissions equivalent to carbon dioxide (MTCO₂E).

As shown in Table 1, CHP LFG project financials can be as much as 100% better than a traditional engine generator project using LFG.

Table 1. LFG Cost Model Estimates for 3 MW Project with and without CHP Financial Results and Environmental Benefits.

	<i>Standard SI Engine</i>	<i>CHP with SI Engine</i>
Assumptions:		
Project Size	3 MW	
Initial Year Product Price	4.5 cents per kWh	4.5 cents per kWh and \$7.50 per MMBtu of waste heat
Financial Results:		
Internal Rate of Return	11%	23%
Net Present Value	\$52,174	\$2.0 million
Installed Capital Cost		
at Year of Construction	\$3.7 million	\$5.6 million
Payback (years)	15	8
Annual Environmental Benefits (MTCO ₂ E)*	16,000	21,700

*Greenhouse gas reduction benefits calculated in units of metric tons of emissions equivalent to carbon dioxide (MTCO₂E).

These LFGcost analyses are preliminary estimates and should be used for general guidance only. Projects for specific landfills require unique design modifications and may add to the cost predicted by LFGcost. A detailed final feasibility assessment should be conducted by a qualified LFG professional prior to preparing a system design, initiating construction, purchasing materials, or entering into agreements to provide or purchase energy from a LFGE project.

CHALLENGES AND INCENTIVES

Potential LFG users may not have considered the benefits of LFGE for several reasons. First, it is not a common fuel. The end user may be concerned about its reliability, or may believe their process requires commercial fuels and energy systems.

Users must also determine how their energy demand corresponds with the relatively stable LFG production rate from a nearby landfill. If an industry's energy demand is seasonal, CHP applications provide an opportunity to balance LFG utilization between electricity and other energy demands. Natural gas can be blended with LFG or other auxiliary fuels to add energy necessary during peak periods. Operating risk can be minimized through power purchase agreements (PPAs) that tie LFG costs with the price of the commercial gas supply.

Financing can pose a barrier to LFGE projects because of high upfront capital costs or competition with low electricity prices in some markets. The collection system, pipeline, and project investment can be significant for a landfill that has not yet developed a gas management system. But an end user interested in green power can offset some of the financial risk with long-term agreements that provide steady future revenue for the landfill and continuing energy cost savings for the user.

Some of the incremental capital cost of CHP can be offset for LFGE projects because LFG is considered a renewable biomass fuel. It is included in the renewable and alternative energy programs of most states. Because electricity from LFG is available now, and at a competitive cost (4 to 7 cents per kWh), it serves as a "baseload renewable" for many green power programs.

New federal, state, and voluntary energy programs provide incentives for LFGE in many ways. LMOP tracks the financial incentives for LFGE, including tax credits, grants, low interest loans, and green power

programs at the state and Federal level. LMOP has an interactive online funding guide that presents these funding programs and incentives (<http://www.epa.gov/lmop/res/guide/index.htm>). The CHP Partnership also tracks and posts CHP-related funding opportunities in its own online guide [9].

Federal incentives include Section 45 Tax Credits enacted as part of the Energy Policy Act of 2005. CHP LFGE projects generate electricity using a qualifying renewable fuel source. CHP LFGE projects meeting Section 45 criteria can achieve a Renewable Energy Production Tax Credit of 1 cent per kWh. However, at the present time however, the Energy Policy Act requires that qualifying projects must be placed into service by December 31, 2008. Many private developers are implementing their LFGE projects on this tight schedule to receive the tax credit.

Another green financial incentive has been created by new state and non-profit alternative energy programs. Renewable Energy Credits (RECs), sometimes called "green tags," allow electricity providers and users to buy electricity that are not generated from fossil fuels.

As of December 2006, 23 states and the District of Columbia have enacted Renewable Portfolio Standards (RPS) or Renewable Portfolio Goals that include LFG as a renewable resource. In these state programs, the Public Utility Commission or environmental agency may certify new green energy projects on the basis that they were developed after a given year or that they use approved green power technologies such as wind and LFG. The electricity produced by these facilities is assigned a REC for each kW of electrical output, and the electric companies are required to buy and sell enough green power to meet the RPS standards. In other words, they must purchase enough RECs to represent a required percentage of their electricity sales. The RECs provide a revenue stream for the renewable energy projects.

For example, in Massachusetts RECs are assigned to electricity from wind, solar, hydro, and biomass projects developed after 1997. In 2007, electric retailers are required to have a minimum 3% of their sales backed up with state-certified RECs. The percentage increases to 4% in 2009. The RECs from state-certified projects are being sold for more than 4 cents per kWh today [10]. Since 1997, 13 LFGE projects have commenced operation. LMOP estimates an additional 4 MW of potential from the remaining four landfills considered to be candidates for LFGE project development [5].

New Jersey worked with the PJM Interconnection system in the

Mid-Atlantic region to develop data tracking for green electricity to meet its RPS. The Generation Attribute Tracking System (GATS) started in 2005 and includes megawatt-hours (MWh) produced, emissions data, fuel source, location, state program qualification and ownership of attributes for each MWh tracked. By 2008, electricity suppliers in New Jersey must have 6.5% of their electric portfolio produced from renewable resources [11]. New Jersey is home to twelve LFGE electricity generating projects, one of which is CHP. LMOP considers three more landfills in the state to be candidates for a LFGE project, which could add an additional 4.5 MW to state's LFGE portfolio [5]. New Jersey's Clean Energy Program also has a CHP Program [12].

Companies with internal policy requirements to reduce their environmental footprint can also purchase RECs. Dupont currently buys 170 million kWh per year from biomass and LFG. Pitney Bowes obtains 10% of electricity from wind and LFG, and Staples buys 46 million kWh per year of RECs, 90% of which is from biomass and LFG [3].

Table 2 presents a comparison between a 3 MW CHP project with and without a REC incentive of 2 cents per kWh to highlight the impact of RECs on the CHP LFGE project from Table 1. This comparison includes the same financial and technical assumptions used in the comparison from Table 1.

Table 2. Financial Impact of a REC on a CHP Engine Project.

	<i>CHP with SI Engine</i>	<i>CHP with SI Engine</i>
Assumptions:		
Project Size	3 MW	
Initial Year Product Price Assumption	4.5 cents per kWh and \$7.50 per MMBtu of waste heat	
Green Power Incentive	2 cents per kWh	No
Financial Results:		
IRR	37%	23%
Net Present Value	\$4.0 million	\$2.0 million
Payback (years)	4	8

A variety of direct financial incentives at the state level is also helping projects move forward. Several states are using a mix of incen-

tives including low interest loans, grants, and tax incentives to offset the high cost of capital for renewable or alternative energy projects. For example, Pennsylvania's Energy Harvest Grant Program has awarded grant money for the purchase, construction, and installation of a variety of renewable and alternative energy projects including LFGE projects, like the CHP project at Creswell and Frey Farm landfills in Pennsylvania. North Carolina has a Golden LEAF Foundation (www.goldenleaf.org/) that has been used to fund LFGE at municipal landfills. These grants support LFGE projects that can improve social and economic conditions in the community.

Some states have exempted LFGE and other alternative energy projects from state taxes. Exempting LFGE generating equipment from state sales and use taxes or from state property taxes can be a powerful incentive. Maryland's Clean Energy Incentive Act is an example of a program providing tax credits to facilities that produce energy from biomass (including LFG). Qualifying facilities can claim a credit on their state income taxes.

Another potential source of funding for CHP LFGE projects is through the sale of carbon credits on a carbon market. These credits are generated as a direct result of the collection and destruction of methane and as offsets from using a renewable energy source to generate electricity.

The Lancaster County Solid Waste Management Authority, mentioned in a case study earlier in this paper, has sold some of the carbon credits from its CHP LFGE project on the Chicago Climate Exchange (CCX). CCX is a voluntary but legally-binding greenhouse gas reduction and trading program in North America, which verifies the CO₂E reductions from renewable projects and creates "Carbon Financial Instruments" that can be sold to other CCX members. Between January 2006 and January 2007 the market grew from \$1.10 to \$4.00 for a Carbon Financial Instrument [13].

Landfill Methane Outreach Program (LMOP)

The LMOP works to reduce methane emissions by promoting the development of cost-effective and environmentally beneficial LFGE projects. The more than 600 LMOP Partners include private and public landfill owners and operators, LFGE industry companies, state organizations, energy users and generators, and local communities. LMOP assists LFGE stakeholders in addressing technical and institutional barriers for

LFGE project development.

LMOP provides a variety of tools and services to assist stakeholders in evaluating project potential. LMOP tools, such as the LMOP Database, LMOP Locator Tool, Benefits Calculator, and LFGcost model, which help identify landfill technical and geographic data as well as evaluate the financial and environmental benefits of a project. The LMOP web site (www.epa.gov/lmop) contains a list of LFGE projects and landfills that may be good candidates for a LFGE project, technical documents, case studies, and funding opportunities. In addition, LMOP offers public relations services including publishing Request for Proposal (RFP) announcements for LFGE by e-mail listserv and newsletters and providing publicity and representatives for ribbon cutting events.

LMOP also provides workshops and presentations at energy, environmental, and trade conferences to promote the use of LFG to parties who may not yet have considered the potential of this biomass fuel.

CONCLUSION

LFGE projects, especially CHP projects, are becoming even better prospects in today's escalating energy market, which is acquiring a taste for renewable power. U.S. EPA LMOP provides support for the development of these projects, which produce more environmental benefits than a typical LFGE electricity project and make more efficient use of the renewable LFG resource.

Today only a few LFGE projects benefit from CHP design. But, LMOP is working with more and more companies, like SC Johnson and BMW, who are installing CHP LFGE projects in their facilities to cut energy costs and reduce their greenhouse gas emissions.

LFGE projects using CHP technology are a win/win/win opportunity. They represent renewable energy achievements resulting in higher efficiency, environmental gains, and an improved bottom line.

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