WORLD RESOURCES INSTITUTE
CORPORATE GUIDE TO
GREEN POWER MARKETS

SUSTAINABLE ENTERPRISE PROGRAM & ECONOMICS PROGRAM

Opportunities with Landfill Gas

INSTALLMENT 2

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Introduction

Companies are finding that garbage can improve their bottom line. Landfilled garbage produces a naturally occurring gas that can be used to displace conventional fossil fuels. Landfill gas provides corporations and power producers with a significant business and environmental opportunity to transform a harmful waste by-product into an environmentally beneficial and potentially cost-saving fuel source. General Motors (*see Case Study on page 14*), Ford Motor Company, BMW, Daimler-Chrysler, Nestle U.S.A., General Electric, and International Paper have all discovered that landfill gas is a financially attractive alternative to conventional fuels.

The *Corporate Guide to Green Power Markets* is based on the experience of the Green Power Market Development Group, a unique partnership between the World Resources Institute and 10 leading companies dedicated to building corporate markets for green power. The corporate energy professionals supporting the Group have extensive experience managing, procuring, and developing a broad range of energy and renewable energy projects. As transparency is an important ingredient in creating a robust renewable energy market, the Group intends for this series to inform corporate energy managers about how to incorporate green power into their energy portfolios.

This second installment focuses on the Group's experience in their pursuit of landfill gas-to-energy (LFGTE) opportunities. During the past 2 years the Group has met with engineers and developers to review potential LFGTE projects and evaluate their environmental and economic viability. Several members have since contracted with developers or are developing their own LFGTE projects.

This report is intended to provide corporate energy managers with a basic understanding of the environmental, technical, and economic issues underlying a LFGTE project. In particular, this publication will:

- provide an introduction to landfill gas as a renewable energy source,
- present a business and environmental case for LFGTE,
- outline important aspects of implementing LFGTE projects, and
- identify policy actions that would facilitate the further development of landfill gas as a source of green energy.

What Is Green Power?

Various definitions of green power exist. The Green Power Market Development Group has defined "green power" as energy sources that are commonly accepted as having a relatively low impact on human, animal, and ecosystem health. Under this definition, green power encompasses renewable energy sources including solar (PV and thermal), wind, biomass, landfill gas (for electricity and for direct use), and geothermal, as well as "clean" energy technologies, such as fuel cells and microturbine systems. How "clean" fuel cells are depends on the source of the hydrogen and the quantity of CO_2 and other pollutants that are emitted in producing the hydrogen. The environmental benefits of microturbines are also sensitive to fuel choice. In considering green power projects, the Group also takes into account the life-cycle impacts associated with "clean" energy technologies.

Greenhouse Gas Glossary

Greenhouse gas (GHG) is any gas that absorbs infrared radiation in the atmosphere. GHGs include, but are not limited to, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrochlorofluorocarbons (HCFCs), ozone (O_3), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6).

Radiative forcing is a change in the balance of incoming solar radiation and outgoing infrared (thermal) radiation. GHGs in the atmosphere trap an increased fraction of infrared radiation and redirect it back towards the earth, creating a warming influence.

Global warming potential (GWP) is the index used to translate the level of emissions of various gases into a common measure in order to compare the relative radiative forcing of different gases without directly calculating the changes in atmospheric concentrations. GWP of a greenhouse gas is the ratio of global warming, also known as *radiative forcing*, from one unit mass of a GHG to one unit mass of CO_2 over a period of time (usually 100 years). Global warming potentials are used to express GHGs in terms of CO_2 equivalents. (*See Table 1.*)

Carbon dioxide equivalent (CO_2e) is a metric used to compare the emissions of different GHGs based upon their GWP. CO_2e is derived by multiplying the tons of gas by its GWP. For example, methane has a GWP of 23, so that one million metric tons of methane is equivalent to 23 million metric tons of CO_2e.

Source: U.S. Environmental Protection Agency, Global Warming web site, www.epa.gov/globalwarming.html.

LANDFILL GAS FUNDAMENTALS

Landfill gas is the natural by-product of bacteria decomposing the organic materials contained in landfills. Landfill gas is composed of approximately 55 percent methane and 45 percent carbon dioxide (CO_2), along with small amounts of nitrogen, oxygen, hydrogen, less than 1 percent nonmethane organic compounds (NMOC), and trace amounts of inorganic compounds.[1] The Btu value, composition, and volume of landfill gas determine its potential uses. These attributes are influenced by several variables:

- the type of waste in the landfill (i.e., the percentage of refuse that is organic);
- the moisture content and temperature of the landfill, which is largely influenced by the surrounding climate; and
- the current and projected amount of municipal solid waste (MSW) at the landfill.

Uses of Landfill Gas

Overview: There are two primary uses for landfill gas. The first is as a ***medium-Btu gas*** (approximately 550 Btu per standard cubic foot) for use as a fuel for electricity generation or used directly in fossil fuel-consuming equipment such as boilers. The second is as a ***high-Btu gas*** (approximately 1,000 Btu per standard cubic foot after processing to remove the carbon dioxide) that can be blended with natural gas. The main components of a landfill gas project include:

- a gas collection system and a flare to ensure that there is no gas buildup in the landfill,
- a gas treatment system to remove volatile organic compounds (VOCs) and condensate, and
- equipment configured to combust landfill gas.

The Group has found that the most environmentally and economically attractive use of landfill gas, particularly in the absence of policy incentives such as production tax credits, is a medium-Btu "direct-use" application.

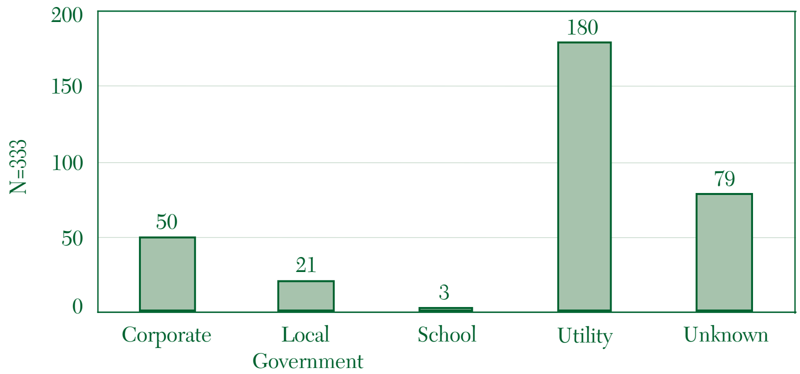
Where a direct-use application is not feasible, using landfill gas as a fuel for electricity generation also provides environmental benefits through the offset of electricity generated by fossil fuels.

Table 1 Global Warming Potential of Selected Greenhouse Gases

Gas	Lifetime in Atmosphere *(years)*	GWP *(100-year time horizon)*
carbon dioxide (CO_2)	50–200	1
methane (CH_4)	12	23
nitrous oxide (N_2O)	114	296
sulfur hexafluoride (SF_6)	3,200	22,200

Source: Intergovernmental Panel on Climate Change (IPCC) Climate Change 2001 Synthesis Report, p. 189.

Figure 1 **End Users of Operational LFGTE Projects in U.S.**



Source: EPA, Landfill Methane Outreach Program, August 10, 2002.

The economic benefits of an electricity project are closely tied to a project's size and equipment cost. Conversion of landfill gas into a high-Btu fuel requires high volumes of gas and sustained high natural gas prices to be financially viable. The Group has focused on the use of landfill gas in medium-Btu direct-use and electricity generation applications as the most feasible for commercial and industrial energy customers.

Direct Use: The simplest application of landfill gas is using it as a medium-Btu fuel and piping it directly from the landfill to a nearby facility that can consume the gas in boilers or other equipment that can be modified to utilize landfill gas. Using landfill gas directly requires removal of impurities (such as heavier hydrocarbons and trace amounts of inorganic compounds) and condensate at the landfill, as well as a pipeline to transport the gas to the end-use facility. End users typically (but not always) need to be within 5 to 10 miles of the landfill, as the capital and operating cost of a dedicated pipeline longer than 10 miles can make the net cost of delivered landfill gas noncompetitive with traditional fuels. These geographic limitations can be a significant hurdle for those seeking landfill gas opportunities.

Electricity Generation: The geographic limitations and need for equipment modification associated with direct use can be overcome by using landfill gas to fuel electricity generation equipment (reciprocating engines, combustion turbines, fuel cells, or microturbines) located at the landfill. Electricity can be transmitted to the local electric grid or, potentially, directly to an end-use facility. The most common technology for electricity generation, utilized in 82 percent of all landfill gas-to-electricity projects, is the reciprocating or internal combustion engine.[2] In general, reciprocating engines have proven to be the most cost-effective and reliable technology for electricity generation from landfill gas, especially for moderately sized projects. Gas turbines are an option for landfill gas projects that can support generation capacity of at least 3 to 5 megawatts (MWs). In addition, several facilities are using microturbines and fuel cells for landfill gas applications.

Government Regulation

Recovery and combustion of the organic compounds found in landfill gas are regulated under the 1996 U.S. Environmental Protection Agency's (EPA's) New Source Performance Standards (NSPS) and Emissions Guidelines (EGs) for Controlling Existing Sources, as well as the National Emission Standards for Hazardous Air Pollutants (NESHAPs). These regulations require that large MSW landfills (those with a design capacity of at least 2.5 million metric tons and 2.5 million cubic meters as well as an uncontrolled nonmethane organic compound emission rate of at least 50 metric tons per year) collect landfill gas. The regulations are intended to either reduce NMOC emissions by 98 percent or keep the outlet concentration to less than 20 parts per million per volume (PPMv). These reductions can be achieved through energy recovery devices or simple combustion (flaring). Although no regulation specifically controls methane emissions, destroying NMOCs via combustion does result in the reduction of methane emissions. Smaller MSW landfills are not required to control emissions by the NSPS or NESHAP.

LFGTE projects can also be affected by EPA regulation in *nonattainment areas*—areas of the country where ozone and nitrogen oxide (NO_x) air pollution levels exceed the national ambient air quality standards—since the combustion of landfill gas emits some NO_x. In nonattainment areas, using landfill gas directly as a displacement fuel for steam or heat applications can be a preferable alternative to combustion, since direct use emits less NO_x than either flaring or electricity generation.

In a few cases, the condensate collected from processing landfill gas may include components from trace gases that are regulated by the EPA under the 1976 Resource Conservation and Recovery Act (RCRA). This would require that the condensate be treated as a hazardous waste, reported, and removed in accordance with RCRA regulation.

Landfill Gas-to-Energy Projects in the United States

LFGTE projects have established a strong track record over the past 10 years. Many companies are successfully utilizing landfill gas directly in their facilities or for electricity generation. According to the EPA's Landfill Methane Outreach Program (LMOP), 15 percent of operational landfill gas projects have corporate end users. (*See Figure 1.*) This includes companies from the automotive, cement, chemical, food product, refining, mining, and other industrial sectors.[3]

Table 2 Installed and Potential LFGTE Capacity in the U.S.

	Operational	In Construction	Planned
Direct Use	**104** 45,807,500 MMBtu	**12** 5,110,000 MMBtu	**95** 30,112,500 MMBtu
Electric Generation	**229** 977 MW	**28** 120 MW	**89** 277 MW
Total	**333**	**40**	**184**

Source: EPA, Landfill Methane Outreach Program, August 10, 2002.

The LMOP reported that 333 LFGTE projects were operational as of August 2002. An additional 40 projects are under construction and 184 projects are planned. Sixty percent of these completed and under-construction projects generate electricity (approximately 1,100 MWs), and the remainder use landfill gas directly as a fuel for heat and steam generation, displacing approximately 51 million MMBtus of natural gas or coal per year. (*See Table 2.*) The LMOP estimates that an additional 400 existing landfills are currently large enough to support future projects.

THE ENVIRONMENTAL CASE FOR LANDFILL GAS

Capturing methane from landfills provides a significant opportunity for global and local environmental improvement:

- Landfills are the major contributor to atmospheric methane emissions in the United States, accounting for 35 percent of all domestic anthropogenic methane emissions.[4]
- Recovery of landfill gas can also reduce emissions of NMOCs and VOCs.
- Local pollution and environmental hazards can also be decreased with landfill gas collection.

In terms of reducing global climate change, LFGTE projects promote greater methane collection efficiency given the value placed on methane as a fuel. Improved collection efficiency reduces methane emissions, and thus reduces atmospheric concentrations of GHGs.[5] Methane is a radiatively and chemically active trace gas with 23 times the global warming potential of carbon dioxide.[6] Methane's radiative activity causes it to trap infrared radiation, or heat, enhancing the greenhouse effect, making it a major contributor to the warming of the Earth's atmosphere, second only to CO_2.

In 1978, the global average concentration of methane was measured to be about 1.51 parts per million by volume. By 1996, the concentration of methane had risen to about 1.73 PPMv. This rapid increase in methane concentrations also is confirmed by analyses of infrared solar spectra, which show that methane concentrations have increased by over 30 percent since 1951.[7] However, because methane's chemical lifetime is approximately 12 years, this GHG is an excellent candidate for mitigating the impacts of global warming because emission reductions could lead to stabilization or reduction in methane concentrations within a 10- to 20-year timeframe.

Locally, the buildup of gases within a landfill can pose a public health and environmental hazard. For instance, NMOCs consist of hazardous air pollutants (HAPs) and trace amounts (less than 1 percent) of VOCs. NMOCs can contribute to smog formation and VOCs may be carcinogenic. Furthermore, the buildup of methane in landfills can be an explosive or fire hazard. LFGTE projects can also significantly reduce the odors associated with landfills.

THE BUSINESS CASE FOR LANDFILL GAS

There are clear benefits for commercial and industrial companies to procure landfill gas:

- The potential to decrease energy costs.
- The potential to reduce price volatility.
- The opportunity for securing emission reduction credits.
- An increased ability to improve a corporate environmental profile through sustainable energy use and net GHG reductions.

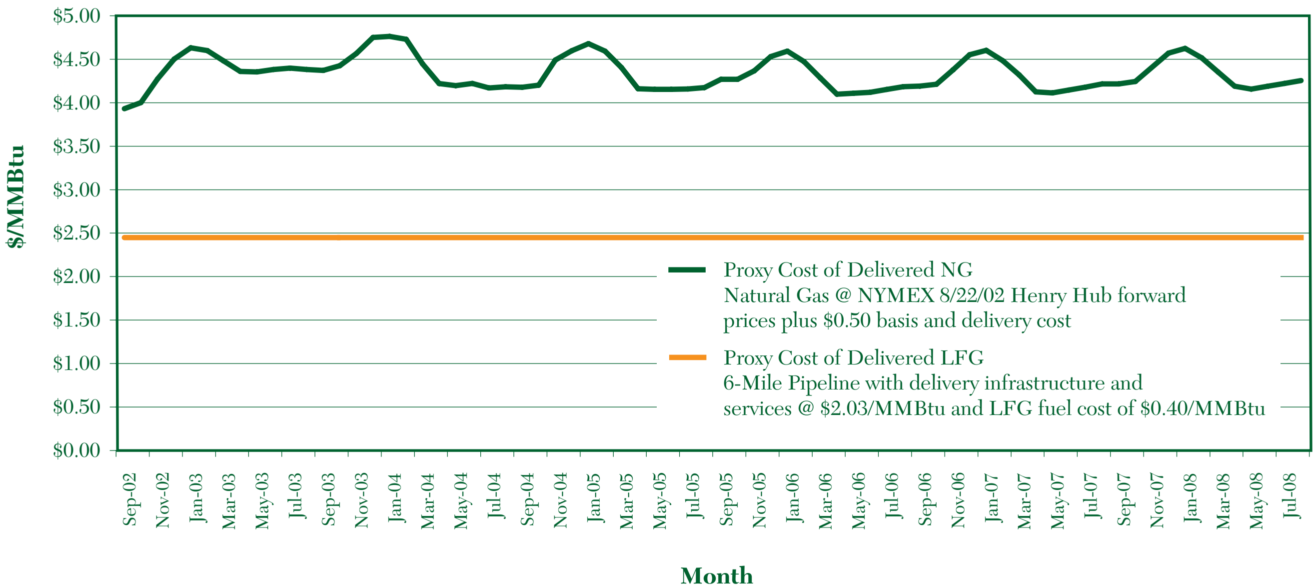
Renewable fuel sources such as landfill gas can act as a long-term price and volatility hedge against fossil fuels, especially natural gas and oil. The link between the price of natural gas and the price of electricity has increased substantially as more electricity is generated from natural gas each year. LFGTE projects provide a long-term supply of energy that can displace market purchases of natural gas, providing fuel at low, stable prices. *Figure 2* illustrates the price competitiveness and stability of a direct-use landfill gas project as compared to the projected cost of natural gas based on forward market prices at Henry Hub. (Henry Hub is the largest centralized point for natural gas spot and futures trading in the United States.)

In addition to reduced price volatility, an LFGTE project provides two GHG emissions reduction opportunities. First, it requires methane from the landfill to be collected, thereby preventing the gas from escaping into the atmosphere. Second, it displaces the CO_2 emissions from the fossil fuels that would otherwise have been used. Under the right set of incentives and policy frameworks, landfill gas projects may be able to generate revenue through the sale of GHG credits. Transactions have already taken place both internationally and in the United States. For example, in 1999 Zahren Alternative Power Corporation (ZAPCO) sold 2.5 million tons of CO_2 emission credits from 20 LFGTE projects in the United States to Ontario Power Generation, Inc. in Canada.[8] In June 2001, the Dutch utility Nuon purchased more than 300,000 tons of CO_2 emission credits from a GSF Energy LFGTE project in New Jersey.[9]

It is important to note, however, that the market for CO_2 emission reduction credits is just beginning to develop globally, and the accounting standards and methodology for measuring and inventorying emissions and related offsets are still in their very early stages of development. It is uncertain how the United States will enter this market—whether by joining the international market or by establishing a national regulatory or voluntary system. The Bush administration has proposed a voluntary system for U.S. GHG reductions, improvements to the federal GHG Reduction and Sequestration Registry (1605b), and the establishment of rules to protect and provide transferable credit for emission reductions. However, the mechanics behind these proposals and how they might interconnect to the international market have yet to be established.[10] Pending decisions on markets, registries, and GHG accounting rules will likely have significant implications for corporate demand for landfill gas and other forms of green power.

Figure 2 **Price Competitiveness of Landfill Gas in a Direct-Use Application**

Proxy Cost of Delivered Natural Gas vs. Cost of Delivered Landfill Gas



Source: Vince T. Van Son.

Many leading corporations, including Group partners Alcoa, DuPont, General Motors, IBM, and Johnson & Johnson, also have adopted goals for environmental performance and established public or internal targets for greenhouse gas emission reductions. Procurement of landfill gas to displace fossil fuels can greatly reduce a corporation's net GHG footprint and improve its corporate environmental profile.

IMPLEMENTING LANDFILL GAS PROJECTS

Companies can implement LFGTE projects in two ways:

- contract with an LFGTE developer, or
- develop the project on their own, either by utilizing internal expertise or by hiring an engineering firm to act as an owner's agent.

The Group found that first-time landfill gas-related transactions require a significant amount of organizational learning. Corporate procurement, finance, and legal professionals have had many concerns related to transaction details such as price, quality, and reliability of supply; supplier credit ratings; and liability issues resulting from landfill operations, landfill contents, or the condensate removed from landfill gas. These factors, coupled with the fact that commercial agreements are somewhat project-specific, increase transaction costs.

LFGTE developers who have implemented many projects can bring a great deal of expertise to project development. Developers can evaluate and manage issues from landfill gas composition to permitting to operation and maintenance. LFGTE developers can also absorb the financial risk and liabilities of developing landfill gas projects.

Although contracting with a developer can greatly ease implementation of LFGTE projects, the Group found that industrial consumers are in many cases positioned to lower project costs by leveraging existing internal resources, capabilities, financial and energy supply positions, and commercial relationships. For example, in addition to existing assets, industrial enterprises may have existing relationships with engineering firms, equipment manufacturers, or construction contractors. These relationships can provide synergies relative to project development that can result in cost savings.

Engineering, procurement, and construction costs (EPC) are the major cost components of a landfill gas project. By unbundling and optimizing EPC costs through coordination or internalization of key activities such as equipment procurement, an industrial consumer may be able to make a significant contribution to lowering a project's total cost. Many industrial and commercial users already possess corporate resources, infrastructure, and local and national presence that can be leveraged to facilitate landfill gas development. Corporate goodwill and existing relationships and familiarity with permitting agencies and processes can also reduce development time and cost.

Another means to reduce costs is for industrial or commercial end users to retain a professional engineering and development firm experienced in landfill gas projects to act as an owner's agent and manage the optimal assembly of key elements of the value chain. An owner's agent also can help to reduce project risks and facilitate organizational learning and receptivity to landfill gas projects.

Screening Landfills for LFGTE Projects

The LMOP has outlined four criteria for identifying good candidate sites for LFGTE projects:

1. The site has at least 1 million tons of MSW in place.
2. The site either is still receiving waste or has been closed for less than 5 years. (Landfill gas production tends to peak just after the closure of the landfill.)
3. The depth of the landfill is 40 feet or more.
4. The site already has a gas collection system in place (this criterion is not necessary, but can improve the economic viability of the project).[11]

Once a landfill site satisfies these criteria, determining the projected annual gas supply for the next 15 to 20 years is the next critical step for establishing the technical scope and attendant economic feasibility of any LFGTE project. According to LMOP, of the operational LFGTE projects, the average landfill gas energy recovery facility collects just over 2.5 million cubic feet per day (approximately 57 MMBtu/hr) of landfill gas, although the size of feasible projects can vary considerably.[12]

Choosing Landfill Gas Applications

In general, the Group found that medium-Btu direct-use applications are the most environmentally and economically attractive, but they typically require a customer within a nominal 5 to 10 mile radius that can utilize the gas. Electricity generation projects have the advantage of being able to harness the Btu value of landfill gas at any landfill location and export electricity to the local electric grid.

Direct Use: In the United States, 40 percent of *all* LFGTE projects and 90 percent of LFGTE projects with *corporate end users* are medium-Btu direct-use applications.[13] Direct-use applications provide the most thermally efficient use of landfill gas and the greatest opportunity to be cost-competitive with traditional fuel alternatives. In contrast to landfill gas-to-electricity projects, direct-use projects also can have significantly lower capital costs. This enables the associated infrastructure to be scaled to take advantage of the total volume of collected gas and minimize the amount of gas wasted through flaring.

There are several issues that the corporate energy manager should be aware of with regard to direct-use applications. For instance, it may be necessary to invest in equipment or processes that are capable of switching between landfill gas and traditional fuels given the accommodations that must be made for variability of flow, Btu value, and impurities in the landfill gas. The initial cost of incorporating landfill gas into a facility can be significant. Costs include investments in dedicated gas transportation infrastructure, changes to fuel distribution systems and equipment such as boilers, and additional accommodations to address reduced supply and related equipment reliability. The long-term investments, commitments, and associated risks borne by customers must be taken into account when negotiating a transfer price for the gas.

Electricity Generation: On-site conversion of landfill gas to electricity mitigates the key constraint of direct-use projects—having a facility that can utilize the landfill gas within close proximity to the landfill—and expands the potential customer base for landfill gas to the entire electric market. In some instances it may be possible for electricity to be delivered directly to a customer's facility, thereby helping the customer reduce its transmission and distribution costs.

Electricity generation projects are inherently more complex than direct-use projects and carry a larger financial risk due to the increased scope and cost of equipment and operations. Project risks for both direct use and electricity generation exist in the areas of development, operations, regulation, and margin (cost vs. market value). Fuel risk (quality and quantity of supply) is also common to both types of projects. Unlike direct use, however, electricity projects require additional permitting for a new source of emissions, electric interconnection infrastructure, and commercial arrangements for interconnection and sales.

Given that most commercial and industrial customers purchase electricity on a retail basis and that most landfill gas project owners only sell on a wholesale basis, an advantageous transaction structure between a LFGTE project owner and a corporate customer is a contract for differences (CFD). (*See Figure 3.*) This approach allows a customer in a deregulated electric market to contract with any licensed generator for the type of physical generation service desired while having the price indexed to the hourly price of a regional power pool that has liquidity and price transparency. The retail customer also enters into a financial contract (the CFD) with an LFGTE project owner, whereby each party is obligated to pay or receive from the other party the difference between the contract price and the actual regional power pool market price. The CFD firms up the price of the variable priced retail generation supply contract. The CFD structure also permits the corporate consumer to keep its regional market price position independent of any given facility, thereby facilitating the ability to make a long-term commitment. A CFD strategy allows the corporate energy buyer to support the development of a landfill gas project and also to be insulated from the many commercial details associated with development and operation of a project.

Economic Evaluation of LFGTE Projects

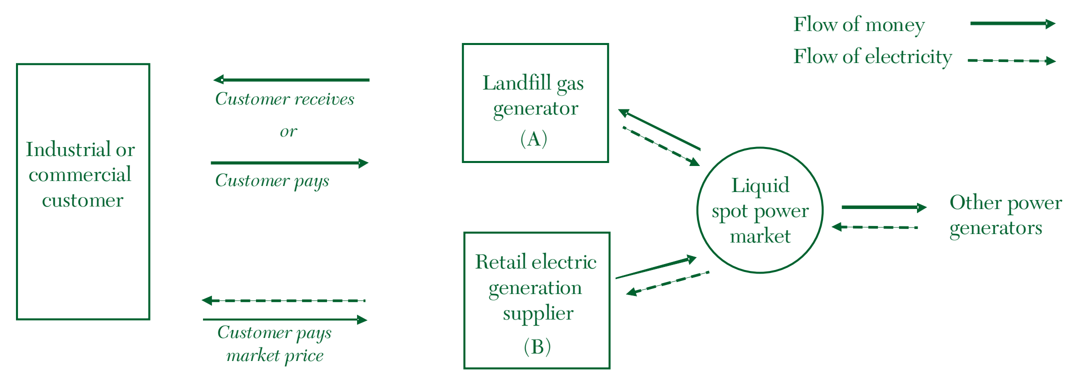
Although most corporate energy consumers will not be developing their own LFGTE projects, it is useful to understand the underlying components of the LFGTE value chain in order to unbundle the pricing in direct-use or electricity generation projects. The Group found it essential to understand the underlying costs for an LFGTE project, whether they were evaluating projects they would develop themselves or negotiating a contract for fuel or electricity generation.

The following information should be obtained to assess the viability of any landfill gas project:

- current consumption volume and patterns for fuels that might be displaced with landfill gas (natural gas, coal, propane, diesel, or fuel oil);
- exact location of the landfill gas supply relative to location of equipment that will consume the gas, as well as the types of property that lie between (this will largely determine if it is feasible for the landfill gas to be delivered directly to an end consumer);
- historical data on amount of landfill gas collected (MMBtu/hr) and projection of future landfill gas supply;
- ability for the consumer to make a long-term commitment (10 years or longer);
- ability for the consumer to partner with a government or other entity with a lower cost of capital or other advantages to reduce capital and/or operating costs;
- estimated cost of landfill gas;

Figure 3 **Contract for Differences**

Customer signs contract for differences with a landfill gas generator (A)



Customer signs contract for physical supply with retail electric supplier (B) based on spot market

If the contract for differences is set at...	and the market price is...	the amount the customer receives from (pays to) the landfill gas generator is...	and the net cost to the customer is:
$40/MWh	$55/MWh	$15/MWh	$40/MWh
$40/MWh	$30/MWh	($10/MWh)	$40/MWh

Source: Vince T. Van Son.

- cost to install or retrofit equipment as necessary to consume landfill gas; and
- cost of generation and competitiveness relative to alternate supply options.

In order to develop an accurate financial model to screen the financial viability of LFGTE projects, companies can enlist engineering and consulting firms with experience with direct-use and electric generation projects. The Group energy managers worked extensively with engineering firm Cummins & Barnard Inc. to develop the financial models contained in this installment. The underlying data contained in these financial models are based on a database built on the experience of both Cummins & Barnard and the Group with actual LFGTE projects, as well as discussions with suppliers of landfill gas, equipment, and contract services. The models are relatively conservative, and represent typical costs based on the Group's experience, absent of any site-specific premiums or discounts. It is important to note that total project development, procurement, construction, and operating costs are site and project specific and can vary considerably based on a number of factors, including:

- cost of equipment (new vs. used, ability to secure discounts, etc.);
- project size (i.e., 1 MW or 10 MW);
- risks taken relative to development, construction, and operation;
- distance between the landfill and application;
- capacity and location of the point of interconnection to the local grid (for generation projects); and
- types of development, construction, and/or operation synergies with other projects.

The financial models present the projected fixed, variable, and capital recovery costs necessary to provide after tax cash flows which yield a 9 percent return on invested equity (zero debt) over 15 years assuming a 35 percent tax rate and a fuel cost of $0.40/MMBtu. The underlying assumptions reflect the Group's estimates for typical costs for each of the key elements. *(An interactive version of these financial models, where assumptions can be changed, is available on the Group's website,* ***www.thegreenpowergroup.org/publications****.)*

Capital recovery costs account for a significant portion (40 percent or more) of total costs for both direct-use and electricity generation projects. (*See Figures 4 and 5.*)

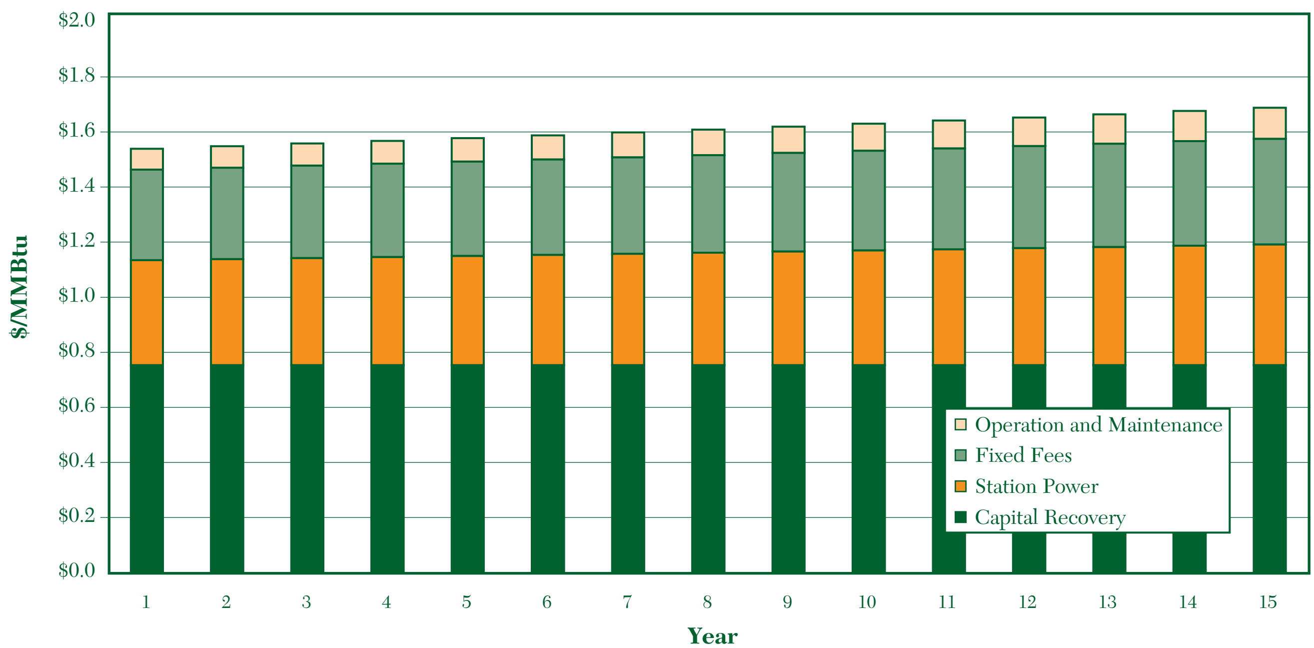
The key determinants of the capital recovery charge include:

- total project cost,
- applicable incentives (state or federal tax credits or other incentives that act as a second source of revenue or capital),
- required internal rate of return,
- financial leverage (debt/equity ratio),
- cost of debt and equity,
- depreciation schedule, and
- applicable tax rate.

Direct Use: The 15-year average revenue required to recover all costs for a 52.5 MMBtu/hour direct-use landfill gas project fueling two 50,000-pound-per-hour steam boilers and provide a 9 percent internal rate of return to develop, construct, and operate a 2-mile pipeline and associated boiler retrofit is estimated at $1.61/MMBtu. If the length of the pipeline were tripled to 6 miles, the threshold revenue would increase to $2.03/MMBtu. Typically, the cost of landfill gas would be additive at a nominal value of about $0.40/MMBtu. This would result in the total delivered cost of landfill gas ranging between $2.01 and $2.43/MMBtu. (*See Table 3.*) The capital and operating costs of a dedicated pipeline make the net

Figure 4 **Cost of Infrastructure for Proxy Direct-Use Project (52.5 MMBtu/hr)**

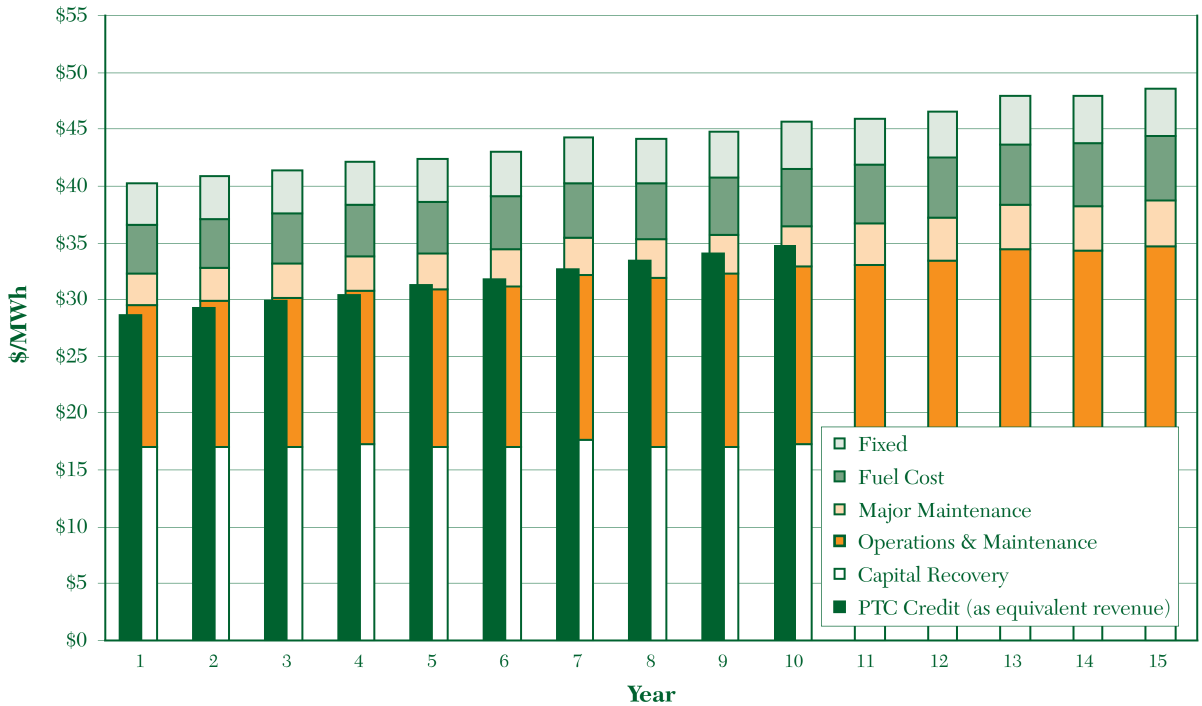
Cost of 2-mile pipeline with capital recovery at 9% IRR, unlevered (cost of fuel excluded)



Source: William Damon, Cummins & Barnard and Vince T. Van Son.

Figure 5 **Cost of Generation for Proxy 5 MW Electricity Generation Project**

Capital at $1,050/kW with capital recovery at 9% IRR, unlevered



Source: William Damon, Cummins & Barnard and Vince T. Van Son.

cost of fuel delivered directly a function of distance and capacity.

Electricity Generation: The 15-year average revenue required for a 5 MW landfill gas-to-electricity project without any advantaged cost structure can range from $44 to $48/MWh. (*See Table 4.*) Changes in one or more elements of operating cost can quickly increase or decrease the revenue required to support a generation project.

Relative to the cost of generation from more traditional fossil fuel-generating facilities, which determine the market price for electricity based on regional balance of generation supply and demand, landfill gas-to-electricity projects have a significant fuel cost advantage. The cost of landfill gas to an electric generator from landfill sites with an existing collection system may range from $0.20 to $0.40/MMBtu versus $1.20/MMBtu for coal or $3 to $4+/MMBtu for natural gas. On a unit basis, landfill gas can provide a fuel cost advantage from $7+/MWh relative to coal to $20/MWh or more relative to natural gas-fueled generation.

However, the fuel cost advantage provided by landfill gas (under many natural gas price scenarios) will be more than offset by the combined higher capital cost ($/kW of installed capacity) and higher operating and maintenance costs common with much smaller scale generation projects. A combined cycle combustion turbine facility can produce electricity for approximately $44/MWh on a continuous basis with natural gas at $4/MMBtu. The average market price of generation will vary based on the cost of generation from the last unit dispatched to meet demand during any given period. Therefore, a production tax credit or other significant incentive is typically essential to mitigate the

Table 3	Direct-Use Landfill Gas Project	
	52.5 MMBtu/hour Direct-Use Model *(15 year capital recovery period at 9% IRR, unlevered, cost of fuel not included)*	
	Total Project Cost	**15-Year Average Revenue Needed for Infrastructure ($/MMBtu)**
2 Mile Pipeline	$2,300,000	$1.61
4 Mile Pipeline	$2,950,000	$1.82
6 Mile Pipeline	$3,600,000	$2.03

Source: William Damon, Cummins & Barnard and Vince T. Van Son.

gap between the market price of generation and the higher cost of generation from landfill gas. As illustrated in ***Figure*** 5 and ***Table*** 4, a production tax credit of $0.018/kWh could reduce the 15-year average revenue required to a range of $20 to $23/MWh.

Further complicating the gap between cost of generation and market price can be the need for generated electricity to be integrated into the wholesale power market. Three issues add to the price gap:

1. **Delivery:** The buyer (or the seller) must arrange for and pay to deliver the generated electricity from the project, often interconnected at low voltage and located in a particular regulated distribution service territory, to a regional wholesale power market at transmission-level voltage. The cost to deliver electricity varies by utility and can add $2 to $6/MWh to overall costs.

2. **Integration:** The cost to integrate bulk power into the wholesale marketplace (sell and schedule) is relatively fixed and independent of the number of megawatts transacted. The small and atypically sized 3 to 5 MW output common to many landfill gas projects is more costly to integrate on a unit basis than conventional electricity transactions, which are generally made in 50 MW blocks.

3. **Unit-Contingent Pricing:** Landfill gas-generated electricity is often sold as a unit-contingent product, as opposed to the more commonly traded, financially firm products that provide liquidated damages in the event of nondelivery. Unit-contingent products typically are sold at a discount since they leave the energy buyer vulnerable to spot market pricing during those times the landfill gas project is not generating electricity.

Ultimately, the gap between the cost of energy from an LFGTE project (fuel or electricity) and a consumer's alternative will determine project viability. Project scale, capital costs relative to the amount of energy delivered, and applicable incentives to pay down capital costs are key determinants in the cost of any LFGTE project. Incentives, particularly for electricity generation, are important in promoting the development of landfill gas projects.

Table 4	Electric Generation Landfill Gas Project	
	5 MW Electric Generation Model *(15-year capital recovery at 9% IRR, unlevered)*	
Total Project Cost	**15 Year Average Revenue Needed for Capacity and Energy without PTC ($/MWh)**	**15 Year Average Revenue Needed for Capacity and Energy with PTC ($/MWh)**
$1,150/kW	$48	$23
$1,050/kW	$46	$21
$950/kW	$44	$20

Source: William Damon, Cummins & Barnard and Vince T. Van Son.

Case Study: General Motors Fort Wayne Truck Assembly Plant—Direct Use of Landfill Gas

By Daniel Voss, Senior Project Engineer, General Motors

General Motors (GM) is the world's largest vehicle manufacturer, employing approximately 362,000 people globally with manufacturing operations in more than 30 countries. In 1991, the GM board of directors adopted corporate Environmental Principles to encourage environmental consciousness in both daily conduct and in the planning of future products and programs, creating a mandate to pursue green technologies and procurement strategies. In 1999, GM Utility Services began evaluating all of its sites for the potential use of landfill gas. As the list of candidate sites was narrowed, the business case at each potential location was evaluated and the best opportunities pursued. This process continues at GM as the availability of landfill gas and the needs of the plants change over time.

Sourcing renewable energy at the Fort Wayne Truck Assembly Plant in Indiana presented an opportunity for energy managers to act on GM's environmental principles, reducing emissions of local air pollutants as well as global greenhouse gases. The plant was a good candidate to utilize landfill gas directly given its three natural gas-fired boilers, significant steam load throughout the year, and location near a large landfill. The landfill is located about 9 miles from the plant and was able to supply 400,000 MMBtu of gas annually. This volume is expected to increase to 550,000 MMBtu per year by 2006. Engineering studies estimated that gas would be available from the landfill for the next 30 years.

The direct use of landfill gas in one of the boilers presented an attractive business case. The gas could be used to meet base load requirements and, based on experience from previous landfill gas projects, the gas system could be designed to use a minimal amount of natural gas to "top off" the fuel stream due to the variable flow of the landfill gas. The project has resulted in considerable business advantages for the Fort Wayne plant including:

- $500,000 in savings per year compared to the 5-year average price of natural gas in Fort Wayne, and
- insulation from natural gas market fluctuations through a fixed price contract for landfill gas.

Although this was not GM's first landfill gas project, it presented many challenges. The first hurdle was working with the developer to make the project economically feasible given the 9-mile pipeline required. The second hurdle was maintaining corporate support for a single energy project representing a small fraction of GM's overall energy load. The third hurdle was the length of time required to implement the project—2 years from concept to startup:

- 8 months for regulatory approvals,
- 6 months for air permits,
- 5 months for pipeline approval and construction,
- 4 months for boiler conversion,and
- 3 months for corporate approval.

Fourth, many different parties were involved in the project, thereby necessitating time-consuming and extensive communication. The final hurdle was startup and integration of the boiler using landfill gas without disrupting plant production.

The developer had total responsibility for installation and construction of the landfill gas capture and delivery system, including compressors, dryers, collection systems, pipeline construction and right-of-ways, and boiler conversion. While GM provided some financial assistance to enable early pipeline construction, the car manufacturer provided no capital for the project.

To ensure complete integration of the landfill gas system with existing natural gas systems, GM hired a controls engineer to manage the flow and mixing of gases. This was particularly important given that Indiana requires daily balancing of natural gas and it was necessary for GM to access the landfill gas meter in order to avoid balancing penalties.

There were several factors key to the success of the project:

- The site utility manager championed the project and was instrumental during the installation and startup phase.
- GM already had worked successfully with the developer on a prior project.
- Use of local contractors in the construction of the project generated community support.
- The significant savings generated by the project facilitated plant and senior management acceptance and approval of the project.

While the landfill gas projects implemented by GM have required more work in terms of operation and maintenance compared to a natural gas boiler, the economic and environmental benefits have greatly outweighed these issues. GM has also found that its employees, especially the plant operators, feel "pride of ownership" in the landfill gas projects, recognizing the projects are good for the environment and for their community.

POLICY INCENTIVES FOR A MORE COMPETITIVE GREEN POWER MARKET

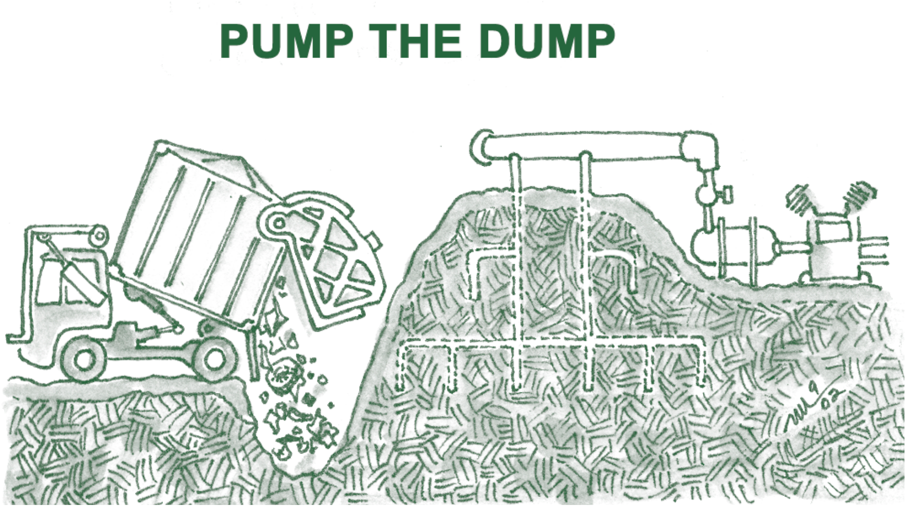
Broad public policies, such as production tax credits and net metering, and standards for assigning value to emission reductions, such as standardized GHG reduction formulas, are needed for landfill gas and other green power sources to be cost-competitive in the current energy market. WRI and the Green Power Market Development Group support both public policy activities and developing standards for GHG accounting in our collaboration.

Production Tax Credits: The Group promotes the reinstatement of production tax credits for electricity generated from landfill gas. Bridging policies such as short-term tax provisions can play a vital role in encouraging investment in green power until emission credits for the environmental attributes of green power are in place.[14]

Net Metering: In regulated and deregulated electric markets, a significant mechanism for increasing consumer demand for green power is net metering. Net metering provides owners credit for generation from specific (renewable) resources as if the generation assets were located on site and netted against the electric meter of one or more of the owner's retail loads. Net metering is especially important for promoting the development of relatively small-scale renewable resources such as landfill gas generation projects since it helps the projects realize a higher net value for the power produced. Another important attribute of net metering is that it can be implemented in both regulated and deregulated electric markets.

Standards for GHG Accounting: There are currently no widely accepted standards for quantifying the GHG reduction credits from landfill gas (or any other) projects. Currently, states are developing their own inventory rules, registries, and legislation concerning GHGs. The lack of a single, national accounting standard creates uncertainty and could greatly increase the transaction costs for participating in the GHG market. A nationally and internationally accepted accounting standard that includes the emission offsets from renewable energy projects would provide significant support for a robust green power market.

Development of a harmonized international protocol is underway. The Greenhouse Gas Protocol Initiative (GHG Protocol)[15] is being developed by a broad international coalition of businesses, nongovernmental organizations, and governmental bodies operating under the umbrella of WRI and the World Business Council for Sustainable Development (WBCSD). The GHG Protocol aims to develop credible and practical guidance on GHG accounting. The GHG Protocol has already been used by several current international and state emission inventory programs and registries including those in France, the United Kingdom, California, Wisconsin, and the New England region. The EPA is also using the GHG Protocol as the measurement and reporting basis for its new Climate Leaders Initiative—a voluntary GHG reduction program for industry. Further details on emission inventories and registries will be addressed in Installment 3 of the *Corporate Guide to Green Power Markets*.



SUMMARY

For the corporate customer, procurement of landfill gas can provide clear benefits by potentially lowering energy costs and price volatility compared to fossil fuel, securing emissions credits, and improving a corporation's environmental profile by helping it take an active step to reduce methane emissions, and thus global warming. Many companies are taking advantage of this local and renewable energy resource and at least fifty projects with corporate end users are operational in the United States. While 90 percent of these projects are direct-use applications, opportunities and transaction structures that can support using landfill gas to generate electricity already exist (such as contract for differences).

While procurement can be challenging, many companies have already found LFGTE projects both cost-competitive and environmentally sustainable. The Green Power Market Development Group will continue to support policy that promotes the use of landfill gas, and will continue to pursue landfill gas opportunities as an important strategy in creating a sustainable energy future.

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