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Landfill Gas to Fuel

By Jeremy Williams, Policy Analyst
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Introduction

Daily, there are millions of tons of municipal solid waste deposited into thousands of landfills and other dumping sites, worldwide. The decomposition of organic material in these places—typically food and paper products—results in the production of methane and other greenhouse gases. Landfill gas (LFG) typically is made up of 50 percent methane (CH_4) and 50 percent carbon dioxide (CO_2), with small amounts of non-methane organic compounds often present.[1]

Methane is the second largest of the five categories of anthropogenic, or human-related, greenhouse gas emissions[2], subsequent only to carbon dioxide emanating from fossil fuels, comprising about 9 percent of all anthropogenic greenhouse gas emissions.[3] Methane concentrations in the atmosphere have more than doubled over the last two centuries, particularly since the advent of the industrial revolution, indicating an increase in methane emissions from anthropogenic sources.[4]

Various factors determine the level of methane emissions in each country or region. Waste management practices, the types and sizes of agricultural and manufacturing industries, the types of energy sources and the ways they are used, as well as the climate of a region, all affect methane emissions. Temperature and moisture, for instance, affect the level and rate of anaerobic digestion, a key component of both anthropogenic and natural methane production. A second major factor in the amount of methane emitted in a particular region or country is the amount that is collected and used—the amount trapped before it is emitted.

The methane in LFG is what can be burned off or used as an alternative fuel. Methane is a far more puissant greenhouse gas than carbon dioxide. Due to methane's ability to trap heat, it warms the earth 23 times more than carbon dioxide and has an atmospheric lifespan of about 12 years,[5] one much shorter than that of other greenhouse gases.[6] Reductions in the level of methane currently in the atmosphere can drastically be reduced or eliminated within a short period of time, if proper action is taken. Short lifespan, along with its high heat-trapping potential, make methane elimination from the atmosphere a particularly effective method of combating global warming. Many experts contend that LFG recovery projects that use methane for fuel have become effective tools for combating the effects of global climate change.

LFG recovery projects have existed since the late 1970s. According to the U.S. Environmental Protection Agency (EPA), as of December 2006, there were approximately 425 LFG recovery projects operating in 43 states. These sites supply at least 74 billion

cubic feet of LFG to end users and generate approximately 10 billion kilowatt hours of electricity every year. Collectively, these projects supply a variety of direct-use projects with 230 million cubic feet of LFG per day. In addition, the EPA has estimated that the environmental benefits and energy savings from these projects are equivalent to annually: planting 19 million acres of forest; supplementing the consumption of 150 million barrels of oil; eliminating the carbon dioxide emissions from 14 million cars; or offsetting the use of 325,000 railcars full of coal.

LFG recovery projects involve many different types of participants and contributors, including private and public entities, small and large landfills, and an assortment of technologies and equipment used for delivery, conversion and production. The types of facilities that use recovered methane gas include: warehouses and other operational facilities of private manufacturing companies; recreational facilities; wastewater treatment plants; schools; correctional facilities; and on-site landfill facilities themselves. The EPA approximates that there are around 600 additional landfills that offer an economically feasible opportunity for LFG recovery and use.[7]

An important question regarding methane as a greenhouse gas is how and by what it is produced. Methane emissions happen both naturally and due to behavior specific to human beings. The four major natural sources of methane emissions are: wetlands, termites, oceans and hydrates—methane trapped in ice. The major anthropogenic sources of methane emissions are: landfills, processes involving natural gas production, animal husbandry, coal mining and refinement processes, and manure management.

Natural Causes

Natural causes of methane emissions contribute to about 40 percent of all emissions, with anthropogenic causes responsible for the rest. The primary natural methane-producing entity is global wetlands, which are responsible for about 76 percent of the natural methane emissions in the world. These wetlands are home to methanogenic bacteria that emit the gas while decomposing organic material. Since all methane production requires an anaerobic, or oxygen-free, environment, along with organic material, wetlands are an optimal location for methane production, as they contribute more than three-fourths of the natural methane emissions in the world.

The second leading natural cause of methane emissions is termites. Each species of termite produces different amounts of methane, and studies have shown that the actual amount emitted from species to species can vary greatly, and the climate in which the termite lives can affect the level of emissions as well. The gas is produced in the termite's digestive track, which involves the breakdown of cellulose by symbiotic micro-organisms. These emissions contribute approximately 11 percent of natural methane production globally.

Third, the world's oceans are responsible for approximately 8 percent of natural methane emissions. Methane is produced during the anaerobic digestion of marine zooplankton and fish. Although this type of methane production is most prevalent in larger bodies of water, methanogenesis can occur in some sediments and drainage areas in coastal regions.

Finally, methane hydrates—methane trapped in ice—account for about 5 percent of the naturally occurring global methane emissions. They are created at low temperatures and high pressures as clathrate compounds (a substance in which a molecule of one compound fills a cavity within the lattice of another compound). Basically, frozen water molecules encase and trap methane gas molecules. These compounds are typically found in sea-floor sediments and the arctic permafrost. Currently, methane hydrates are the only naturally occurring source of methane that have the potential to be harnessed as a fuel source.[8] Former President Bill Clinton signed the Methane Hydrate Research and Development Act in May 2000, which authorized approximately $50 million over a five-year period to be dedicated to developing methods for utilizing methane hydrates, which are clean-burning when utilized as an energy source. The potential to use this form of methane as a fuel is uncertain, since so little is known about the quantity and stability of these compounds. Estimates for energy use from hydrates range anywhere from 350 to 3,500 years. The use of hydrates for storing carbon dioxide also is being explored.[9]

Anthropogenic Causes

Although natural causes play a substantial role in methane production, human beings are culpable for about 60 percent of the creation of the gas that is released into the atmosphere. There are various anthropogenic causes for methane emissions, but the decomposition of landfill waste contributes the greatest amount of anthropogenic methane emissions, accounting for about 24 percent in the United States (about 34 percent of total methane emissions globally). Annual global methane emissions from landfills are approximated to be between 30 and 70 million tons, most of which is emitted from developed countries that have high levels of waste.

However, there are other major anthropogenic causes, such as processes associated with natural gas

production, transmission, storage and distribution. Methane is the primary component of natural gas and is released in varied amounts during these procedures. Since natural gas often is found with crude oil, the production, refinement, transportation and storage of oil frequently contributes to methane emissions as well. Altogether, methane emissions released from natural gas contribute to 23 percent of all anthropogenic sources.

Another major human-related factor of methane release is animal husbandry. Ruminant animals (cattle, buffalo, sheep, goats, and camels) emit considerable amounts of methane during their normal digestive processes. Microbial, or enteric, fermentation in the large fore-stomach, or rumen, of these domesticated animals produces methane as a byproduct of the digestive process, which either is immediately eructed by the animal, or is absorbed into the bloodstream and later exhaled. Emissions of this type contribute to approximately 21 percent of the anthropogenic methane emissions in the United States. Methane is produced during the digestive processes of animals and also during the handling of dried manure, but only in insignificant amounts.[10]

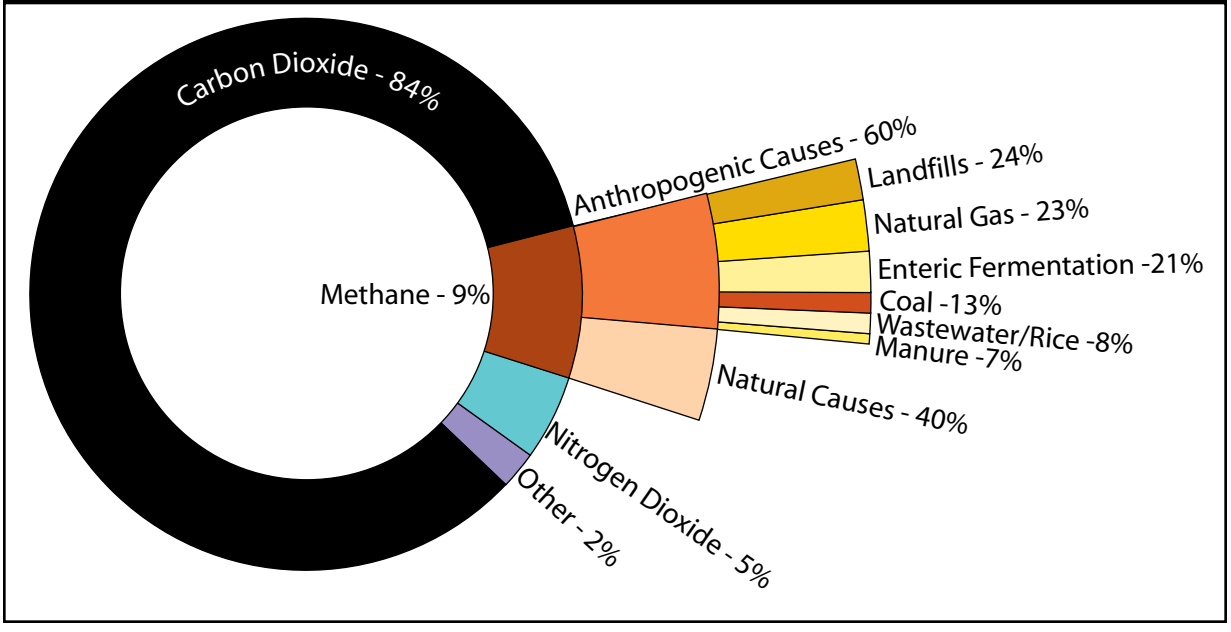
The anaerobic decomposition of the organic material found in livestock manure also causes moderate amounts of methane production, and contributes to about 7 percent of the anthropogenic methane emissions in the United States. Although the emissions are minimal, operations such as liquid manure management systems found at large dairy farms and other ruminant animal operations can produce high levels of methane and, therefore, are locations where small-scale recovery projects are feasible, particularly as technology continues to advance.

Furthermore, treatment processes of wastewater management and rice cultivation can produce varying amounts of methane, depending on the practices and conditions involved in such projects. In general, about 8 percent of anthropogenic methane emissions come from these practices.

Finally, methane released from coal deposits and the surrounding strata during underground and surface mining, as well as during other coal-refinement processes, is one of the major anthropogenic causes of methane emissions. These emissions amount to approximately 13 percent of the anthropogenic sources of methane production.[11]

The federal EPA has developed various programs to address many of these issues. For instance, the EPA's National Gas STAR Program and the Coalbed Methane Outreach Program assist natural gas, oil and coal mining companies in employing practices to minimize methane release during production, transportation, and distribution of their products, and educate participants on methods for capturing and selling methane gas. Also, the AgSTAR Program encourages similar practices for livestock manure management.[12] In addition, scientists are attempting to determine how to stop or limit the rumen microbes in livestock from producing methane. Finally, there are various criteria set out by the EPA regarding siting, design and operation standards for landfills, along with groundwater and gas migration monitoring requirements.

Figure 1: U.S. greenhouse gas emissions by source



The Processes of Methane Capture and Use

The method by which methane is recovered from landfills involves the use of a series of wells and vacuums that collect the gas. The methane is then sent to a processing and treatment facility, which typically operates on-site at the landfill but can be located between the landfill and the end user, at a separate location, or at the site of the end-user. Several functions exist for gas that has been collected, processed and treated.

The most common use is by utility companies that require natural gas or some other fuel to produce electricity through the operation of engines, turbines or microturbines. Depending on the type of company, its electrical needs, and the amount of methane output from the landfill, the electricity is either used by the company that produces or purchases it, is made available for purchase by local industries, or is sold for use on the local power grid. Another alternative, which requires further refinement of the gas, is to convert the methane into a pipeline-quality transportation fuel for alternative fuel vehicles.[13] Burning methane is more efficient than using natural gas, since LFG has approximately half the heat content of natural gas and burns at a lower temperature.

Methane is released either directly into the atmosphere or through the cover soil. In general, methane recovery systems can reduce methane emissions by as much as half without the use of liners, which often are placed under the landfill to reduce leakage into the surrounding soil and groundwater. It is not uncommon for closed sites that do not have a methane gas recovery project to cover the landfill with a substantial soil layer, so that the methane emissions can be consumed by methanotrophs—bacteria that use methane as a source of carbon and energy—in the soil. Three types of liners typically are used: mineral, geomembranes and composite liners. Mineral liners are made of clay, mudrocks, and soil bentonite admixtures. Geomembranes are thin polyethylene layers. Composite liners are a combination of a geomembrane with some form of mineral lining. It has been estimated that as much as 90 percent of all methane emissions can be recovered and used with the utilization of these liners.[14] Without the use of methane capture and use, the gas is typically flared off, which releases large amounts of carbon dioxide into the atmosphere.

Since LFG is emitted during the bacterial decomposition of organic material found in landfills, there are various factors that affect the quality of the gas that is produced. The types of waste stored in a landfill can affect the rate of decomposition and, therefore, the potency of the emitted gas. Second, the age of the waste contributes to the quality of gas that is emitted from the landfill. Therefore, older landfills that lack collection systems are prime candidates for LFG projects. The surrounding climate—moisture levels and air temperature—can affect the quality of the gas. Finally, the amount of methane created in these landfills depends on the quantity of waste in the landfill and the moisture content of the waste. (Methane is generated only in anaerobic conditions.) Also, methane can be produced in landfills for years after the site is closed, due to continued decay of waste. These factors must be taken into consideration when calculating the potential output of a given landfill.

There are two types of boilers that can operate on LFG: a water wall boiler and a fire tube boiler. A water boiler, typically used in larger, higher-pressure projects, uses tubes filled with water to surround and contain the flame. Fire tube boilers, used in smaller projects, use hot flue gases passing through a tube immersed in water. Adaptations to boilers include adjustments for: a higher volume of gas flow, greater potential for corrosion, and a lower flame temperature.[15] Conversion processes typically are minimal, and although minor modifications may be required for combustion equipment, the benefits for sustaining a constant, reliable, local fuel source far outweigh any inconveniences or costs for acquiring adaptive equipment.

Benefits of Methane as an Alternative Fuel

Since LFG is the largest anthropogenic cause of methane emissions, LFG capture and use programs are extremely vital to addressing the issue of greenhouse gas emissions in general, and the dangers of methane gas in particular. In addition to environmental benefits, there are other reasons companies or public entities should consider initiating LFG capture and use programs. The benefits of capturing these gases fall under three categories: energy related, environmental, and economic.

Energy

Energy benefits contribute to a forward move toward energy independence for the United States. LFG can serve as a reliable, cheap alternative to traditional fuels like natural gas. According to the Energy Information Administration, the United States imports approximately 16 percent of the natural gas it uses to produce electricity.[16] Also, methane gas is used in some projects as an alternative to other fossil fuels, such as coal or oil. While it is most common for methane to serve as a supplement to fuels used for electricity production, like natural gas or coal, engines that run on gasoline can be converted to utilize methane gas as well. With daily oil consumption in the United States exceeding 22 million barrels, any supplement to this reliance is beneficial.

Many companies and public entities have decided to switch from using natural gas or other fuel sources in their industrial and commercial boilers to the use of LFG. One advantage for these companies is having constant and reliable fuel costs, costs that are unaffected by the global fuel market. These projects also help these companies, and other public entities, meet federal renewable energy standards.

Environment

The United States contributes approximately 26 percent of the world's methane emissions, which is, in large part, due to the amount of waste in U.S. landfills.[17] Particularly for the United States, the most feasible opportunity for reducing these emissions is through the capture and use of LFG. Both LFG collection and use projects are important because, unlike many conservation efforts that focus on reducing individual consumption, these projects are a mechanism for private companies, as well as state and local governments, to be involved. Companies, for instance, can amass a number of investment partners for LFG capture and reuse, producing vast results that are unachievable by an individual person, or even individual companies or government bodies.

The largest environmental and public health concern regarding LFG involves surface emissions, simply because the components of LFG are very dangerous. Carbon dioxide and methane are greenhouse gases that contribute to global warming. Other volatile organic compounds, such as benzene, toluene, chloroform, vinyl chloride, carbon tetrachloride, and trichloroethane, may be present in LFG, and can contribute to environmental and health problems as well. Also, LFG contains trace amounts of dioxins and furons, toxic chemical compounds often referred to as "persistent organic pollutants." Although the typical concentration in LFG is fairly minimal, exposure to these gases can lead to serious health problems. Small amounts of mercury exist in LFG as well, and combusting the gas reduces the toxicity by converting it into an inorganic mercury compound. In addition, hazardous air pollutants in LFG can contribute to respiratory illnesses or primary irritation, and even central nervous system damage. The volume of landfills, and eventually the amount of gas being emitted, decreases as the waste decomposes and the methane is drawn off by LFG recovery projects.[18]

In addition to the air pollutants, LFG emissions can seep into the surrounding soil and pose hazards to the surrounding water sources. Subsurface migration, the movement of methane gas from the landfill into the surrounding soil or beyond, is typical in older landfills that do not have lining to keep the gas from escaping.

For landfills that lack some type of lining or protective measure for extracting gas that is accumulating, it is possible for LFG that has escaped to collect underground or in enclosed areas and ignite.

One environmental benefit would be the reduction in the amount of greenhouse gas emissions released into the atmosphere, thereby reducing the effects of global warming and improving air quality, which can alleviate myriad health risks. Although LFG projects have been overlooked in the past, advances in technology (more efficient and safer transfer of gas, cheaper processing, etc.) have accentuated the ability to utilize these programs to offset significant amounts of emissions from fossil fuels that the methane replaces. In fact, the capture of LFG is one of five categories of major devices for offsetting heat-trapping gases under the Regional Greenhouse Gas Initiative, a plan in 10 Northeastern states to cut total carbon emissions from power plants by 10 percent in 10 years.[19]

Although the United States has begun taking steps to reduce these emissions (according the EPA, the total U.S. emissions in 2001 were more than 5 percent lower than emissions recorded in 1990), it is imperative that programs such as these continue to gain federal approval and support, state recognition and endorsement, and local acceptance and implementation.

Economy

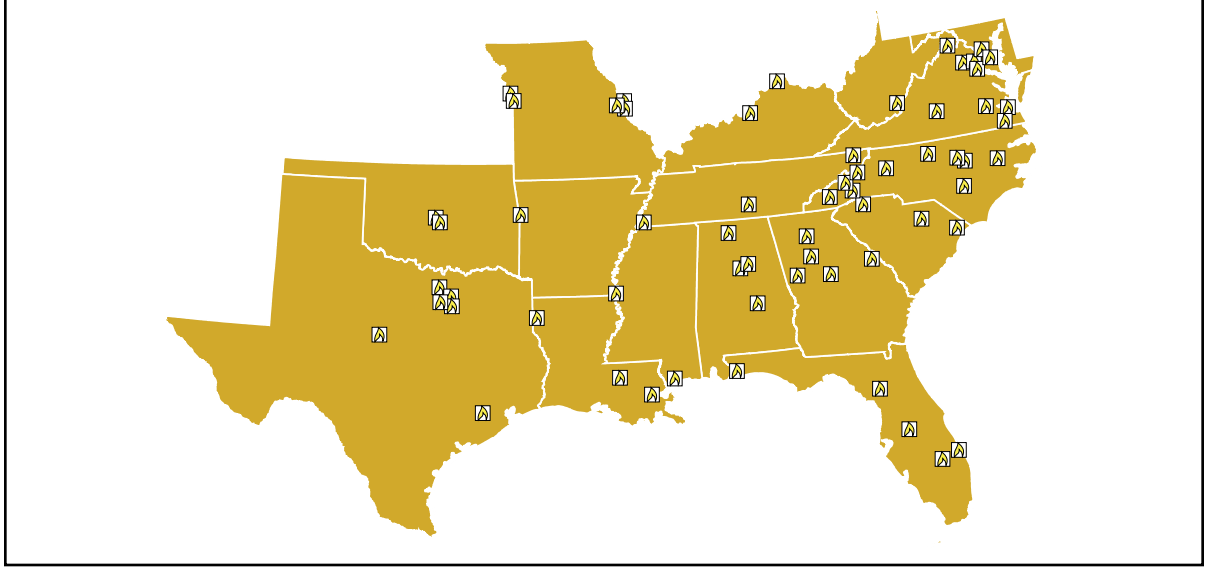
Methane capture and use projects also produce benefits in regard to economic development. Such projects create jobs and cut energy costs for companies. These projects also localize energy sources, stimulating regional economic growth. The EPA has estimated that the average 3 megawatt LFG recovery project, within its first year of operation, will contribute an average of $10 million to the U.S. economy; increase U.S. employee earnings through wages and salaries by more than $3 million; and employ more than 70 people in full-time positions.[20] The EPA also has estimated that the savings after conversion costs are anywhere from 10 percent to 40 percent, and conversion costs are minimal. Investors and developers, however, should recognize that successful projects require access to capital markets.

Government funding supporting these projects, including the conversion of equipment to make use of LFG, have grown in recent years. For instance, the Renewable Electricity Production Credit in the federal Energy Policy Act of 2005 provides various tax credits, as well as other financial incentives, grants and loan guarantees, specifically for projects that recover renewable LFG. Specifically, it gives $0.009 in tax credits for every kilowatt hour sold and produced from LFG.

State Programs

The following section examines 61 major LFG recovery and use projects in the 16 SLC states. Each section details the size of the landfill,[21] methods and means for collecting the gas, ways in which the gas is used, and the financial and environmental impacts of each individual project. The charts at the beginning of each section indicate the number of barrels of oil, acres of forest, number of pollution-emitting vehicles, and the number of heated homes each project displaces in energy use. This information was gathered from landfill operation offices, state Departments of Waste Management, end-users, and the EPA.

Figure 2: Location of landfill gas to fuel facilities in the South



Alabama

Facility»	Recovered Gas Offsets or Is Equal To:			
	Used Barrels of Oil	Acres of Forest	Vehicles Removed from the Road	Heated Homes
City of Birmingham-Sloss Industries LFG Energy Project	19,700	2,300	1,600	5,100
Decatur-Morgan County LFG Recovery Project	180,000	23,000	17,000	5,300
Jenkins Brick Company Jordan Plant Project	166,600	19,600	13,700	4,500
Jenkins Brick LFG Energy Project	26,600	3,100	2,200	6,800
Total	**392,900**	**48,000**	**34,500**	**21,700**

Alabama currently has four LFG projects in operation. The City of Birmingham-Sloss Industries LFG Energy Project is a LFG recovery program owned and operated jointly by the city of Birmingham and DTE Biomass Energy. It began operation in 1998 and utilizes LFG from the Birmingham New Georgia Landfill. The gas is collected by 85 vertical gas collection wells and is processed and sold to Sloss Industries, which then uses it in a nearby facility to fuel two centrifugal blowers. The blowers operate a large steam boiler. The project converts approximately 2.4 million cubic feet of LFG every day, displacing about 5 percent of the annual fossil fuel consumption of this facility.

The Decatur-Morgan County LFG Recovery Project, located in Trinity, Alabama, is owned by the county and is operated by the city of Decatur. The project, which began operation in September 2004, utilizes LFG that is collected in a chain of wells and processed and cleaned by the Granger Gas Production Facility, which then transports the gas through a 6,000 foot pipeline to a sheet metal production facility owned by Nucor Steel. The sheet mill operation uses the processed LFG as a direct thermal resource to light tunnel furnaces in their facilities.

The Jenkins Brick Company owns two projects in the state. A project at the company's Jordan Plant in Moody, Alabama, is a nationally recognized direct thermal project that makes use of a 4.4 million ton waste-in-place (WIP) landfill to produce 40 percent of the company's energy demands. Impressively, Jenkins Brick anticipates that the project will supply 100 percent of its energy needs within the next decade. The company has been using LFG to fuel its brick plant since 1998, which was fueled entirely by natural gas before that time. The Jordan plant receives the gas through a 6.5-mile pipeline that connects the plant to the Veolia Environmental Services Star Ridge Landfill. There are 0.019 million metric tons of carbon equivalents in estimated annual emissions reductions. The project was awarded the Alabama Governor's Conservation Achievement Award for Air Conservationist of the Year in 1999. The Jenkins Brick Company also runs a project in Montgomery, Alabama, which utilizes LFG from the North Montgomery Landfill to heat kilns at the nearby factory. This project, privately funded by DTE Biomass Energy, is a slightly smaller operation than the Jenkins Brick operation in Moody, Alabama, but currently has approximately 7.26 million tons of WIP.

The state of Alabama offers various incentives for LFG projects. The Alabama Biomass Energy Program provides up to $75,000 in interest subsidy grants for alternative fuel programs, such as landfill-gas-to-energy projects, in the state. Although the grant program was originally designed to encourage projects that convert wood waste into fuel, it has been extended to include LFG conversion projects as well.[22]

Arkansas

Facility	Recovered Gas Offsets or Is Equal To:			
	Used Barrels of Oil	Acres of Forest	Vehicles Removed from the Road	Heated Homes
City of Fort Smith High BTU Project	29,200	3,100	2,400	7,500

Arkansas has one LFG project in operation, which is a collaborative effort between the city of Fort Smith Department of Sanitation, Cambrian Energy Development, L.L.C, and South-Tex Treaters. In 2005, a facility that processes approximately 3.5 million standard cubic feet of LFG per day was opened in Sebastian, Arkansas, which utilized LFG from the city of Fort Smith Landfill. The original end-user of the gas was a steel manufacturing facility that was only consuming about 20 percent of the available gas. However, this arrangement was terminated in 2005. In September 2006, Cambrian Energy and South-Tex Treaters began funding the operation of the compressors and other gas-processing equipment used in the original project, which has approximately 2.45 million tons of WIP for usage, and the two companies now sell the processed gas collected from the landfill. Most of the gas is sent to the Arkansas Oklahoma Gas Corporation, a utility company that supplies natural gas to approximately 62,000 residential, commercial and industrial customers in western Arkansas and eastern Oklahoma, as well as a gas marketing firm.

While the state of Arkansas has given, since 1999, various tax credits for costs associated with purchasing, erecting or operating facilities for the production of electric vehicles, fuel cells, and biodiesel facilities, there are no tax incentives for developing or operating LFG projects. Such legislation has been considered, but not adopted. In 2007, the "Landfill Methane Development Act" was introduced to give a 30 percent tax credit for the cost of building and operating a landfill-gas-to-energy projects. However, this legislation failed to gain approval.[23]

Florida

Facility	Recovered Gas Offsets or Is Equal To:			
	Used Barrels of Oil	Acres of Forest	Vehicles Removed from the Road	Heated Homes
Alachua County-Gainesville Regional Utilities Project	245,000	28,700	20,200	1,500
Berman Road Leachate Evaporation Project	35,100	4,100	2,900	9,000
International Paper LFG Energy Project	36,600	4,300	3,000	9,400
Tropicana LFG Energy Boiler Project	20,500	2,400	1,700	5,300
Wheelabrator Ridge Energy Co-Fired LFG Energy Project	366,300	43,000	30,200	9,900
Total	**703,500**	**82,500**	**58,000**	**35,100**

There are five LFG collection projects in Florida, which together replace the use of 703,500 barrels of oil annually, the most of any SLC state. The Alachua County-Gainesville Regional Utilities Project, located at the Southwest Alachua Landfill in Archer, Florida, utilizes emissions from 2.69 million tons of WIP and is a partnership between Alachua County, Gainesville Regional Utilities and the University of Florida's College of Environmental Engineering. The project uses leachate recirculation, a process in which leachate, a solution produced from downward percolating groundwater in landfills, is returned to the landfill, infiltrated into the municipal solid waste, and continues to flow through the landfill as it is treated through biological processes, precipitation, and sorption. This process is beneficial for two reasons. First, the resulting leachate requires less treatment than the original extracted condensate. Second, the extra moisture facilitates the biological processes of decomposition, which results in a greater amount of LFG

production.[24] This ordinarily would be a disadvantage, but with projects that capture and use LFG emissions, speedier, more efficient gas production is favorable. This was the first project that the Florida Department of Environmental Protection allowed to recirculate leachate into a closed landfill. Gainesville Regional Utilities is the end-user of the methane gas produced at the landfill, and uses the gas to fuel a 2.4 megawatt reciprocating engine.

The Berman Road Leachate Evaporation Project, located in Okeechobee, Florida, was established in 1992. The 200-acre Berman Road Landfill, which has approximately 9.84 million tons of WIP, burns captured LFG for on-site leachate evaporation. The project, funded by LFG Specialties, Shaw Environmental, and Waste Management, uses a double composite lining system and a geomembrane cover in order to keep leachate from seeping into the nearby groundwater. The leachate is collected and evaporated in reservoirs heated by the collected methane gas. Evaporation of leachate is preferable to other methods of disposal, since the only byproduct is a condensate that is much easier to dispose of than the derivatives of conventional leachate-treatment processes, with the condensate containing only a small fraction of the original leachate amount.[25]

The International Paper LFG Energy Project is located at the Perdido Landfill in Cantonment, Florida. It collects emissions from the 4.05 million tons of WIP in the landfill. The captured methane gas is used to partially power a mixed-fuel boiler, which is employed by International Paper in pulp and paper mill industrial operations. The paper company is funded partly by DTE Biomass Energy.

The Tropicana LFG Energy Boiler Project is located at the St. Lucie County Phase I Landfill, in Fort Pierce, Florida. The landfill has approximately 4.3 million tons of WIP, the emissions of which are used to fuel a boiler utilized by Tropicana Foods in food production operations. The project is jointly funded by CPL-LEI Systems and PepsiCo.

Finally, the Wheelabrator Ridge Energy Co-Fired LFG Energy Project is located in Winter Haven, Florida, and captures emissions from the North Central Landfill, which has approximately 5.2 million tons of WIP. The processed LFG is used to fuel an on-site wood and tire incinerator. The project, funded by DTE Biomass Energy, is the largest energy-producing LFG capture project in the 16 SLC states.

Georgia

Facility	Recovered Gas Offsets or Is Equal To:			
	Used Barrels of Oil	Acres of Forest	Vehicles Removed from the Road	Heated Homes
Cherokee Brick and Tile LFG Energy Kiln Project	26,400	3,100	2,200	6,800
Clay Mining LFG Application Project	192,800	22,700	15,900	5,200
DeKalb County and Georgia Power LFG Energy Project	40,000	4,700	3,300	2,000
Gold Kist Pet Food Project	46,800	5,500	3,900	12,000
Interface and Milliken Carpet Manufacturing Project	111,000	13,000	9,200	3,000
Total	**417,000**	**49,000**	**34,500**	**29,000**

Georgia currently has five LFG collection projects operating in the state. The Cherokee Brick and Tile LFG Energy Kiln Project, located in Macon, Georgia, utilizes emissions from the 3.5 million tons of WIP at the Macon Landfill. The collected gas is used to fuel brick kilns at the Cherokee Brick and Tile Company. The city of Macon collaborates with the brick company to fund the project.

The Clay Mining LFG Application Project, located at the Richmond Count-Deans Bridge Road Landfill in Blythe, Georgia, makes use of 2.33 million tons of WIP. It routes the gas to the Unimin Kaolin Mine, which uses it to power flash drying equipment for processing mined clay. LandGas Technology assists in funding the project, which is the state's largest energy-producing LFG recovery effort.

Located in Ellenwood, Georgia, the DeKalb County and Georgia Power LFG Energy Project was established to collect emissions from the 8 million tons of WIP at the Seminole Road Landfill. The gas from the landfill is converted to fuel two 3,520 horsepower engines. It is the first green power project for Georgia Power, which has partnered with DeKalb County Sanitation, Caterpillar, GeoSyntec Consultants, SCS Engineers and SCS Field Services to fund and operate the project. DeKalb County solid waste officials received the 2006 Community Partner of the Year award by the Environmental Protection Agency's Landfill Methane Outreach Program for their support of this project. Also, the LFG collection facility displays a unique mural that traces the process of garbage collection, to landfill storage, to LFG production, to gas capture, to returning the gas for use by the original residents and businesses that produced the trash.

Gold Kist partnered with Ameresco and Waste Management to develop a project at the Pine Bluff Landfill in Ball Ground, Georgia. The project uses emissions from the landfill to fuel heating equipment for processing chickens for pet food.

Finally, Interface Corporation, a textile company in West Point, Georgia, harnesses methane from the LaGrange Municipal Landfill. Interface, as well as Milliken and Company, a carpet manufacturing company, collaborated with the city of LaGrange to adapt its boilers to use the LFG, replacing its reliance on the natural gas for fuel. The project has amounted to a multi-million dollar revenue stream from the landfill. The landfill has approximately 3.48 million tons of WIP, and the companies estimate that potential power use from the landfill at about 40 years. The LFG is processed in order to fuel three hot oil boilers and one steam boiler that are integral in the production of heat conditioning equipment at Interface. The project cuts the company's natural gas reliance by approximately 20 percent. The processed LFG also is used in various carpet manufacturing processes at the Milliken plant, and supplements 30 percent of the company's natural gas consumption.

Kentucky

Facility	Recovered Gas Offsets or Is Equal To:			
	Used Barrels of Oil	Acres of Forest	Vehicles Removed from the Road	Heated Homes
East Kentucky Power Cooperative Green Power Program	326,000	38,300	26,900	2,000
General Electric LFG Energy Boiler Project	14,600	1,700	1,200	3,800
Total	**340,600**	**40,000**	**28,100**	**5,800**

Kentucky has two LFG projects. The East Kentucky Power Cooperative Green Power Program is a project located at the Bavarian Trucking Company Landfill in Walkton, Kentucky. The landfill, which has approximately 4.58 million tons of WIP, supplies the fuel for a reciprocating engine of the Cooperative, located within Boone County. The start-up costs for this very large and productive project were approximately $4 million when it first began in September 2003, but the Cooperative anticipates a 10-year payback on the funds that were initially contributed. The project is the first in the state to convert LFG to electrical energy, and also is part of the state's EnvironWatts program, which includes 14 cooperatives that offer customers a choice to purchase energy from clean, renewable energy sources. Such programs are rapidly gaining popularity as industrial and residential consumers consider the environmentally friendly and economically viable options that these programs offer.

The General Electric LFG Energy Boiler Project, based at the Outer Loop Recycling and Disposal Facility in Louisville, Kentucky, collects emissions from the 35.05 million tons of WIP at the landfill. General Electric uses the gas to fuel an industrial boiler at a nearby plant. The project is partially funded by Toro Energy and Waste Management.

Kentucky offers various incentives for LFG collection projects. In August of 2007, the Incentives for Energy Independence Act went into effect. This piece of legislation encourages the development of renewable energy and alternative fuel facilities, such as those that convert LFG to fuel. Depending on the size and scope of the project, the Act provides tax exemptions for building and operating such facilities. It also provides a wage assessment exemption of up to 4 percent for each person employed by these facilities.[26]

Louisiana

Facility	Recovered Gas Offsets or Is Equal To:			
	Used Barrels of Oil	Acres of Forest	Vehicles Removed from the Road	Heated Homes
East Baton Rouge Parish LFG Energy Project	23,400	2,700	1,900	6,000
General Motors-Louisiana LFG Energy Boiler Project	52,600	6,200	4,300	13,500
Jefferson Parish Cytec Industries LFG Energy Project	53,200	6,200	4,400	13,600
Total	**129,200**	**15,100**	**10,600**	**33,100**

Louisiana currently has three LFG collection projects in the state. The East Baton Rouge Parish LFG Energy Project makes use of 10.17 million tons of WIP from the East Baton Rouge Parish Landfill. The LFG is converted for use in a boiler operated by the Deltech Corporation. Ronavar Energy Corporation also contributes to the funding of the project.

The General Motors-Louisiana LFG Energy Boiler Project, located at the Woolworth Road Landfill in Keithville, Louisiana, utilizes LFG from 1.19 million tons of WIP from the landfill. The processed gas is used to fuel a boiler at the nearby General Motors assembly plant. The project is funded by Allied Waste Services, General Motors Corporation, and Renovar Energy Corporation.

The Jefferson Parish Landfill in Avondale, Louisiana, just outside of New Orleans, supplies methane gas from its 7.15 million tons of WIP for the Jefferson Parish Cytec Industries LFG Energy Project. The gas is transported through a 4.2-mile pipeline for processing and use as fuel for a boiler at Cytec Industries, a chemical manufacturing company. Construction of this direct-use project was completed shortly after the disasters of Hurricanes Katrina and Rita, which caused many setbacks in completing the project. Various organizations, such as CPL-LEI Systems, Jefferson Parish Department of Environmental Affairs, Renovar Energy Corporation, Shaw Environmental, Waste Management, as well as Cytec Industries, contributed to the project's completion. The project won the EPA Landfill Methane Outreach Program's 2006 Project of the Year Award.

Maryland

Facility	Recovered Gas Offsets or Is Equal To:			
	Used Barrels of Oil	Acres of Forest	Vehicles Removed from the Road	Heated Homes
Brown Station Road On-Site Electrical Generation Project	45,500	5,300	3,700	2,200
NASA Goddard Direct-Use Project	43,300	5,100	3,500	11,100
Total	**88,800**	**10,400**	**7,200**	**13,300**

The state of Maryland has two LFG collection projects. The Brown Station Road On-Site Electrical Generation Project, which began in 1987, is a partnership between Prince George County, Maryland, Potomac Electric Power Company (PEPCO) and Waukesha Engine Division. The emissions from the Brown Station Road Landfill, which has approximately 8.9 million tons of WIP, are converted to fuel a reciprocating engine owned and operated by PEPCO at the nearby Prince George's County Correctional Facility. The engine generates steam and electricity for the facility. In 2003, the county expanded the project to include the use of four new engines that burn approximately 1.75 million standard cubic feet of LFG every day and generate electricity for the facility. The county sells PEPCO the green energy, which generates about $60,000 per month in revenue for the county.

NASA was the first federal agency to begin using LFG as a power source for its facilities. The NASA Goddard Space Flight Center, located in Greenbelt, Maryland, uses LFG from the Sandy Hill Landfill, which has approximately 5.13 million tons of WIP, to power its buildings. The LFG, transported from the

landfill through a 5.5-mile pipeline, provides energy for two converted boilers that serve all of the NASA facility's heating needs. This public-private partnership, launched in 2003, exists between Prince George's County, Waste Management, Toro Energy, NASA and the EPA's Landfill Methane Outreach Program. The direct-us project saves taxpayers around $400,000 annually, and is projected to save more than $3.5 million in energy costs over the next decade.

The state of Maryland provides various incentives for LFG conversion projects. The Clean Energy Production Tax Credit offers alternative-fuel programs income tax exemptions based on the number of kilowatt hours produced by the facility. These incentives are available for a five-year period.[27]

Mississippi

Facility	Recovered Gas Offsets or Is Equal To:			
	Used Barrels of Oil	Acres of Forest	Vehicles Removed from the Road	Heated Homes
DuPont-Mississippi LFG Energy Boiler Project	79,000	9,300	6,500	20,300

The DuPont-Mississippi LFG Energy Boiler Project, the state's only LFG collection project, collects LFG emissions from the Pecan Grove Sanitary Landfill in Pass Christian, Mississippi, which has around 4.01 million tons of WIP. The gas is used to fuel a boiler at a nearby DuPont chemical plant. The project saves the facility approximately $1 million annually. Financial contributors to the project include CPL-LEI Systems, Toro Energy, and Waste Management.

Mississippi established the Energy Investment Loan Program which offers companies that produce alternatives fuels, such as LFG, up to $300,000 for operation costs. These low-interest loans are granted only to projects that demonstrate a reduction in the receiving facility's energy costs.[28]

Missouri

Facility	Recovered Gas Offsets or Is Equal To:			
	Used Barrels of Oil	Acres of Forest	Vehicles Removed from the Road	Heated Homes
DaimlerChrysler LFG Energy Project	47,000	5,500	3,800	12,000
Fred Weber-Pattonville High School LFG Recovery Project	250,000	29,300	20,600	6,700
Lafarge Cement Kiln LFG Energy Project	28,400	3,300	2,300	7,300
Missouri Pass Leachate Evaporation Project	N/A	N/A	N/A	N/A
Rumble-Fort Osage Greenhouse Project	400	100	40	100
Total	**325,800**	**38,200**	**26,740**	**26,100**

Missouri has five LFG collection projects. The DaimlerChrysler LFG Energy Project, located in Ballwin, Missouri, makes use of the emissions from the 8 million tons of WIP at the Oak Ridge Landfill. The converted gas is transported through a 4.5-mile pipeline used to fuel two boilers at the nearby DaimlerChrysler automobile manufacturing plant in Fenton, Missouri. Since 2002, the plant has used the LFG as a supplement to replace approximately one half of its total energy needs. Onyx Waste Services, which operates the project, was named the Landfill Methane Outreach Program's 2002 Industry Partner of the Year, and DaimlerChrysler was given the 2002 Missouri Governor's Award for Energy Efficiency and the 2002 National Association for Environmental Management's Pollution Prevention Award. Toro

Energy, a Texas company, has played a significant role in funding the project.

The Fred Weber-Pattonville High School LFG Recovery Project is located in Maryland Heights, Missouri, and has supplied LFG to a plant owned by the Fred Weber construction company, for use in an asphalt burner and concrete production boiler since 1992, when the project began. In 1997, the project expanded to include service to the Pattonville High School, located less than a mile from the 5.4 million tons of WIP stored in the landfill, to power the school boilers. The move was prompted by the school's ecology club, which recommended that the school board investigate the possibilities of utilizing this alternative energy source. The expansion of the project was funded partly through a $150,000 loan from the Missouri Department of Natural Resources and a $25,000 grant from St. Louis County Solid Waste Management. Fred Weber construction company assisted in the pipeline assembly for the school. The LFT used in the school's boilers, which formerly used natural gas, saves approximately $27,000 a year. The project start-up and operational costs to the school already have paid for themselves in savings.

The Lafarge Cement Kiln LFG Energy Project uses LFG from the Rumble Landfills I and II, which have approximately 3.74 million tons of WIP, to fuel the kiln at a nearby cement plant owned by Lafarge North American. The project is located in Sugar Creek, Missouri, and is partially funded by CPL-LEI Systems and Waste Management.

The Missouri Pass Leachate Evaporation Project makes use of LFG generated from the 11.94 million tons of WIP at the Missouri Pass Landfill in Maryland Heights, Missouri. The project, funded by Allied Waste Services, Liquid Solutions and Shaw Environmental, uses the gas to fuel on-site leachate evaporation processes.

Finally, the Rumble-Fort Osage Greenhouse Project uses LFG from the 3.74 million tons of WIP at the Rumble Landfills I and II, in Sugar Creek, Missouri. The project, which is partially funded by Waste Management, supplies fuel to the Fort Osage School District's Career and Technology Center.

The state of Missouri offers various incentives for LFG collection projects. In November 2004, Columbia, Missouri, adopted a local renewables portfolio standard that required Columbia Water and Light, the city's municipal utility, to purchase or produce electricity generated from alternative fuel sources, including LFG. The city also instituted an incremental increase for the standards every five years, the first of which was December, 2007. Thus far, the utility is ahead of schedule, using wind and LFG to generate more than 3 percent of its electricity. In June of 2007, Missouri created the Renewable Energy and Energy Efficiency Objective, which included a statewide renewables portfolio standard. It requires all investor-owned utilities in the state to make "a good faith effort" to produce at least 4 percent of their electricity from alternative fuel sources, such as LFG, by the year 2012. The requirement increases to 8 percent in 2015 and 11 percent in 2020.[29]

North Carolina

Facility	Recovered Gas Offsets or Is Equal To:			
	Used Barrels of Oil	Acres of Forest	Vehicles Removed from the Road	Heated Homes
Ajinomoto USA LFG Energy Project	29,200	3,400	2,400	7,500
Buncombe County Sludge Drying Project	55,500	6,500	4,600	1,500
Cargill North Carolina LFG Energy Project	14,600	1,700	1,200	3,700
Catawba County LFG Energy Project	39,000	4,500	3,200	1,900
Cone Mills LFG Energy Boiler Project	60,900	7,200	5,000	15,600
EnergyXchange Renewable Energy Center Project	10,400	1,200	860	280
Henderson County LFG Energy Boiler Project	158,100	18,600	13,000	4,300
Jackson County NC Green Energy Park Project	11,100	1,300	900	300
Mallinckrodt, Inc. Gas Energy Project	29,200	3,400	2,400	7,500
Pitt County Memorial Hospital LFG Energy Project	192,800	22,700	15,900	5,200
Total	**600,800**	**70,500**	**49,460**	**47,780**

North Carolina has 10 LFG projects, the most of any SLC state. The Ajinomoto USA LFG Energy Project is an operation of the pharmaceutical company Ajinomoto, Natural Power and the city of Raleigh, North Carolina, which was developed as a direct-use endeavor at the Wilder's Grove Landfill. The project takes LFG collected from the landfill and routes it to a nearby plant where the gas fuels an 800-horsepower boiler owned by Natural Power of Synergy Company. The steam produced by the boiler is used to heat and power manufacturing processes in the plant, supplying more than 95 percent of the company's steam needs. The project began in 1989 and is expected to operate until 2020, based on the 5.6 million tons of WIP at the landfill. Originally, the boiler burned only natural gas before it was retrofitted to burn LFG. The boiler now has separate fuel lines and can accommodate use of either gas. An additional boiler was installed in 1997.

The Buncombe County Sludge Drying Project collects emissions from the 3.3 million tons of WIP at the Buncombe County Landfill in Woodfin, North Carolina. The gas is processed and used to power a fluidized bed incinerator and gas engines that generate electricity at the Buncombe County Department of Solid Waste wastewater treatment plant. The project has been in operation for 10 years. Enerdyne Power Systems manages the gas extraction system and sells the gas to Buncombe County at a price substantially lower than the natural gas it supplements.

The Cargill North Carolina LFG Energy Project, located in Fayetteville, North Carolina, converts LFG collected from the Cumberland County Landfill, which has approximately 1.65 million tons of WIP. The converted gas is used to fuel a steam boiler, which supplies approximately 20 percent of the company's fossil-fuel needs, and a process heater at the nearby Cargill oilseed processing plant. The fuel is transported through a 2-mile pipeline that runs under the Cape Fear River. While the plant uses LFG for thermal purposes, it also extracts oil from soybeans and converts it to biofuel for use at the plant.

The Catawba County LFG Energy Project, a public-private partnership located in Newton, North Carolina, utilizes gas emitted from the 2.68 million tons of WIP located at the Blackburn Landfill. The gas is transported to a power plant to fuel a 20-cylinder, 1,400-horsepower reciprocating engine that produces electricity for Catawba County. The county then sells the electricity to Duke Power for use on the public power grid. The county partners with McGill Associates, a North Carolina-based engineering firm, and Enerdyne Power Systems, the Landfill Methane Outreach Program 1999 Industry Partner of the Year, in order to fund the project. By converting and using the gas, Catawba County has saved approximately $2.5 million and currently has plans to purchase additional methane burning engines and generators.

The Cone Mills LFG Energy Boiler Project, located in Greensboro, North Carolina, utilizes LFG from the 7.62 million ton WIP at the City of Greensboro Landfill. The gas is used to fuel a boiler at a Cone Mills textile plant, which is co-fired with natural gas or gasoline. The city of Greensboro partnered with CES-LANDTEC, Coen Company, Duke Solutions, and LFG Specialties to fund the project.

The EnergyXchange Renewable Energy Center Project, a unique endeavor in Burnsville, North Carolina, uses gas from the Yancey-Mitchell County Landfill. The gas collected from the landfill's approximately 385,000 tons of WIP, is used to fuel boilers, furnaces and kilns at the EnergyXchange Renewable Energy Center. The facilities, which include glass blowing furnaces, a pottery kiln, and various greenhouses that are used to preserve native, local plants, are situated directly on top of the 6-acre landfill. EnergyXchange is a community-based organization established to meet the energy needs of local artists, along with the general task of using LFG that otherwise would be vented, flared off, or stored. It is anticipated that the landfill will provide fuel for the artists, as well as the greenhouses, for at least the next 15 years. There also is a didactic purpose of the project, in that the greenhouses, which are heated using boilers running on LFG, are located where students can come to learn about the necessary components of local ecosystems. Also, there is a visitor's center where guests can learn more about utilizing LFG for conservation purposes. The project is partially funded by a local community foundation, which provided the initial grant. The Blue Ridge Resource Conservation and Development Council also played an integral role in the development of the project. Additional funding for the $800,000 project came from the North Carolina Department of Environment and Natural Resources, the North Carolina Technological Development Authority, the U.S. Environmental Protection Agency, the U.S. Forest Service, and other private foundations.

The Henderson County LFG Energy Boiler Project supplies gas used to fuel a boiler at a Clement-Pappas food processing plant in Hendersonville, North Carolina. Gas is collected from the Henderson County Landfill, which has 2.1 million tons of WIP. Enerdyne Power Systems has contributed funding to the project.

The Jackson County NC Green Energy Park Project uses LFG produced by the 0.75 million tons of WIP from the Jackson County Landfill. Located in Dillsboro, North Carolina, the project uses the converted gas for fueling steam boilers that heat 7,000 square feet of on-site greenhouses. The Energy Park also uses the gas to fuel three blacksmith studios, and heat captured from production processes are used to run a biodiesel refinery that converts vegetable oil from local restaurants into biodiesel. The project has created 20 new jobs since its inception in 2006, and is the first in the country to use LFG to run a blacksmith shop. For its ingenuity, the Energy Park won the Landfill Methane Outreach Program's 2006 Project of the Year Award. The project currently is planning to open pottery and glass blowing studios, a retail gallery, several classrooms, and a facility for drying botanical and agricultural products.

The Mallinckrodt, Inc. Gas Energy Project, located in Raleigh, North Carolina, uses gases emitted from the 5 million tons of WIP at the North Wake Solid Waste Landfill to fuel a steam boiler at a nearby chemical manufacturing company. Mallinckrodt, the world's largest producer of acetaminophen, partnered with Wake County and the DTE Biomass Energy Project, which actually owns and operates the boiler that supplies nearly half the plant's steam needs. Mallinckrodt currently is considering converting two of its other natural gas boilers so that they can combust LFG as well.

Finally, the Pitt County Memorial Hospital LFG Energy Project uses LFG generated by the 3.06 million tons of WIP at the Pitt County Landfill. The hospital, located in Greenville, North Carolina, utilizes the gas to fuel a steam boiler. The county and the hospital partnered with Enerdyne Power Systems in funding this project.

The number and diversity of LFG project in North Carolina is attributable in part to the many incentives the state offers. The NC GreenPower Production Incentive is a program designed to advance the use of renewable, alternative fuels, such as LFG, in the state. Incentives offered by this program include payments from utility power-purchase agreements, made on a per-kilowatt-hour basis, to projects that use LFG as an alternative fuel. NC GreenPower is an independent, nonprofit organization that was created by state government officials, electric utilities, nonprofit organizations, consumers and renewable-energy advocates. It was the first statewide green power program in the United States when it began in October 2003. Also, the state gives a renewable energy tax credit of up to $2.5 million to LFG collection and conversion projects. The credit is for 35 percent of the cost of construction or purchase of facilities that convert LFG to fuel. Finally, in August of 2007, the Renewable Energy and Energy Efficiency Portfolio Standard was enacted in the state. This requires all investor-owned utilities to produce 12.5 percent of their electricity from renewable energy sources, such as LFG, by 2020.[30]

Oklahoma

Facility	Recovered Gas Offsets or Is Equal To:			
	Used Barrels of Oil	Acres of Forest	Vehicles Removed from the Road	Heated Homes
Southeast Landfill–Campbell Asphalt Project	7,300	900	600	1,900
Southeast Landfill–Georgia Gulf Corporation Project	11,700	1,400	1,000	3,000
Total	**19,000**	**2,300**	**1,600**	**4,900**

Oklahoma has two LFG projects. The Southeast Landfill–Campbell Asphalt Project at the Oklahoma City Southeast Landfill is partially funded by Allied Waste Systems. It utilizes emissions from the landfill to supply fuel for the electrical needs of a nearby asphalt plant owned by Campbell Asphalt. The Southeast Landfill–Georgia Gulf Corporation Project is another operation located at the same landfill. It uses the collected gas to fuel a steam boiler at a chemical plant owned by Georgia Gulf Corporation. DTE Biomass Energy has helped fund this project.

South Carolina

Facility	Recovered Gas Offsets or Is Equal To:			
	Used Barrels of Oil	Acres of Forest	Vehicles Removed from the Road	Heated Homes
BMW Manufacturing LFG Energy Projects	150,300	17,600	12,400	3,000
Horry County-Santee Cooper Green Power Program	306,000	35,900	25,200	1,900
Lee County Generating Station	70,100	8,200	5,700	3,400
Total	**526,400**	**61,700**	**43,300**	**8,300**

South Carolina has three LFG projects. The BMW Manufacturing LFG Energy Projects, located in Greer, South Carolina, utilize the emissions from the 17.46 million tons of WIP at the Palmetto Landfill. The emissions are sent through a 9.5-mile pipeline to the nearby BMW automobile manufacturing plant and are used to fuel the plant's oven burners and heat the paint shop space, which is the largest heat-consuming area of the plant. The LFG provides almost 100 percent of the plant's heating needs, and the project is the world's first automotive paint shop to make use of LFG. Also, the fuel is used in fueling four gas turbine cogeneration units, which supply approximately 25 percent of the plant's electrical needs. In total, nearly 70 percent of the plant's energy consumption is supplied by LFG, and the project annually saves BMW approximately $1 million in fuel costs. The company was awarded the Landfill Methane Outreach Program's 2003 Project of the Year award for its innovative work.

The Horry County-Santee Cooper Green Power Program, located in Conway, South Carolina, utilizes LFG from the Horry County Landfill, which contains 3 million tons of WIP, to fuel a reciprocating engine at the Santee Cooper electric utility. The engine operates three generators that provide 3 megawatts of generating capacity to the power grid, which provides electricity to approximately 9,300 residential customers.

The Lee County Generating Station makes use of emissions from 3.67 million tons of WIP from the Lee County Landfill in Bishopville, South Carolina, to fuel a reciprocating engine at a nearby Santee Cooper utility plant. The project began in 2005 and was Santee Cooper's second green power generating facility. Allied Waste Services and GE Jenbacher also have contributed to this project.

Tennessee

Facility	Recovered Gas Offsets or Is Equal To:			
	Used Barrels of Oil	Acres of Forest	Vehicles Removed from the Road	Heated Homes
Iris Glenn Landfill Gas Energy Project	43,800	5,100	3,600	4,900
Quail Hollow Leachate Evaporation Project	2,700	300	200	700
Solae Direct-Use Project	146,200	17,100	12,000	37,500
Total	**192,700**	**22,500**	**15,800**	**43,100**

The state of Tennessee has three LFG collection projects. The Iris Glenn Landfill Gas Energy Project, located in Johnson City, Tennessee, is a public-private partnership that supplies LFG to the Mountain Home Energy Center. The Center uses the gas from the 3.5 million tons of waste-in-place at the Iris Glenn Landfill, which is transported through a 22,000-foot pipeline, to produce steam, 7.5 megawatts of electric power, and chilled water to a nearby Veterans Administration Hospital, a large civic center, and various buildings at East Tennessee State University. Retrofitting costs were minimal for the project, because the LFG was of such high quality. Johnson City has been commended for the public awareness campaign it launched in conjunction with the coming online of the project. The city saves an estimated $500,000 annually in energy costs as a result of the project. Johnson City, in partnership with Waste Management, operates an educational center at the landfill in order to inform the public of the benefits of landfill gas. Due to the project's tremendous innovation, outreach and achievements, the EPA's Landfill Methane Outreach Program awarded Iris Glenn Landfill Gas Energy Project the 2007 Project of the Year Award.

The Quail Hollow Leachate Evaporation Project, located in Raus, Tennessee, makes on-site use of the 1.82 million tons of WIP from the Quail Hollow Landfill. The project burns LFG emissions in order to fuel burners for on-site leachate evaporation. Waste Management assists in funding the project.

The Solae Direct-Use Project uses LFG to fuel three boilers at a Solae Company food-ingredient manufacturing plant in Memphis, Tennessee. This public-private partnership between Solae, Allied Waste Services, CPL-LEI Systems, Memphis Light Gas and Water, and the Tennessee Department of Environmental Conservation utilizes emissions from the 24 million tons of WIP at the South Shelby Landfill. The gas is processed and sent through a 5-mile pipeline to the plant. The project has significantly reduced the plant's reliance on natural gas to fuel its boilers.

Tennessee provides incentives for LFG collection projects. The Tennessee Energy Division offers low-interest loans of up to $300,000 for alternative energy projects in the state. The loans are designed for businesses with fewer than 300 employees and less than $3.5 million in annual gross sales.[31]

Texas

Facility	Recovered Gas Offsets or Is Equal To:			
	Used Barrels of Oil	Acres of Forest	Vehicles Removed from the Road	Heated Homes
City of Brownwood Leachate Evaporation Project	83,300	9,800	6,900	2,300
City of Dallas-Oncor High BTU Project	190,900	22,400	15,700	49,000
Denton Hybrid LFG Recovery Project	83,200	9,700	6,800	2,200
Frito-Lay Direct-Use LFG Energy Project	20,300	2,400	1,700	5,200
Village Creek Wastewater Treatment Plant Project	65,000	7,600	5,300	3,200
Water Recycling Facility's Sludge Drying Project	208,200	24,500	17,200	5,600
Total	**650,900**	**76,400**	**53,600**	**67,500**

The state of Texas has six LFG projects in operation. The City of Brownwood Leachate Evaporation Project, located in Brownwood, Texas, uses emissions from the 1.3 million tons of WIP at the City of Brownwood Landfill. The gas fuels on-site burners that are used for landfill leachate evaporation.

The City of Dallas-Oncor High BTU Project uses gas from the McCommas Bluff Landfill, which has 26.47 million tons of WIP, to fuel a nearby utility plant owned by Oncor, an energy supply company. E/S Renewable Solutions contributes funding for the project.

The Denton Hybrid LFG Recovery Project, located in Denton, Texas, supplies LFG to a local Biodiesel Industries plant that produces 3 million gallons of biodiesel every year. The gas is collected from the Denton Sanitary Landfill, which contains approximately 2.27 million tons of WIP, and is transported to the plant where it fuels a boiler that produces hot water necessary for the chemical processes involved in converting feedstock, vegetable oils and animal fats into biodiesel. The biodiesel from this plant is used to run the city of Denton's fleet of garbage trucks and other utility vehicles, which operate on biodiesel. Any biodiesel produced beyond what is needed for these vehicles is sold to the public. This project is the first in the world to produce biodiesel solely from another renewable energy source. It won the 2005 Landfill Methane Outreach Program Project of the Year award for its innovative use of renewable fuels in producing other renewable fuels.

The Frito-Lay Direct-Use LFG Energy Project, located in Rosenberg, Texas, utilizes the emissions from the 2.65 million tons of WIP at the Rosenberg Landfill to produce fuel for a nearby Frito-Lay food manufacturing plant. The gas is converted and used to fuel a boiler at the plant.

The Village Creek Wastewater Treatment Plant Project, a collaborative effort between the cities of Arlington and Forth Worth, uses gas from the Arlington Landfill to fuel a gas turbine at the Fort Worth Village Creek Wastewater Treatment Plant. The two cities partnered with Renda Environmental, a non-profit environmental organization, and Renovar Energy Corporation to capture the gas emissions released by the 14 million tons of WIP at the landfill, and transport them through a 4-mile pipeline to the treatment plant. There, the gas is used to fuel two 5.2 megawatt gas turbine generators. In addition, the generators also run on methane gas produced by anaerobic digestion in the local wastewater. For its inventive use of two renewable fuel sources, the project was awarded the Landfill Methane Outreach Project's 2002 Project of the Year Award.

Finally, the Water Recycling Facility's Sludge Drying Project in Garland, Texas, uses LFG produced by the 4.01 million tons of WIP at the Castle Road Landfill. The gas is used to fuel a sludge dryer at the nearby Rowlett Creek Water Recycling Facility. The U.S. Energy Biogas Corporation participates in funding the project.

Various incentives for LFG collection projects exist in Texas. In 1999, the Public Utility Commission adopted the Renewable Energy mandate, which establishes a renewables portfolio standard, a renewable energy tax credit, and renewable energy purchasing

requirements for retailers in the state. In addition, the city of Austin adopted in 1999 a renewables portfolio standard that required the local utility, Austin Energy, to obtain 5 percent of its electricity from renewable sources by December 2004. The city council extended this goal in 2003, requiring 20 percent of electricity sold on the grid to be from renewable energy sources by 2020. In February of 2007, the city council increased the 2020 requirement to 30 percent.[32]

Virginia

Facility	Recovered Gas Offsets or Is Equal To:			
	Used Barrels of Oil	Acres of Forest	Vehicles Removed from the Road	Heated Homes
Bethel Leachate Evaporation Project	44,700	5,200	3,700	11,500
Ciba Specialty Chemical LFG Energy Boiler Project	20,300	2,400	1,700	5,200
Fauquier County LFG Energy Project	153,000	18,000	12,600	950
Frederick County Infrared Tube Heaters Project	4,200	500	300	100
Honeywell LFG Energy Project	131,600	15,400	10,800	33,800
I-95 Landfill – Infrared Tube Heaters Project	100	10	10	30
I-95 Landfill – WWTP Project	26,300	3,100	2,200	6,800
Lynchburg City – Rock Tenn Paper LFG Energy Project	106,000	12,500	8,700	2,900
Total	486,200	57,110	40,010	61,280

The Commonwealth of Virginia has eight operating LFG projects. The Bethel Leachate Evaporation Project uses LFG from the Bethel Landfill, which houses approximately 4.4 million tons of WIP, to fuel on-site leachate evaporation. The project is located in Hampton, Virginia, and is a collaborative effort between the landfill and Waste Management.

The Ciba Specialty Chemical LFG Energy Boiler Project, located in Suffolk, Virginia, uses emissions from the 8.34 million ton WIP SPSA Regional Landfill to fuel a boiler at the nearby Ciba Specialty Chemical plant. The Southeastern Public Service Authority and the U.S. Energy Biogas Corporation have contributed funding to the project.

Two Waukesha reciprocating engines at Pepco Energy Services in Warrenton, Virginia, are fueled by LFG collected by the Fauquier County LFG Energy Project. The gas is produced by the 1.24 million tons of WIP at the Fauquier County Landfill and then is converted and sold on the public power grid. The county's Department of Environmental Services voluntarily installed a gas collection system at the small landfill in 2004, and has made the fuel competitive with power produced from coal, natural gas, and nuclear power plants.

In Winchester, Virginia, Frederick County uses gas from the 3.16 million tons of WIP at the Winchester Landfill to fuel two on-site infrared tube heaters. The heaters supply heat for the entire facility.

The Honeywell LFG Energy Project collects LFG from the Waste Management Atlantic Waste Disposal Landfill, which has approximately 14.5 million tons of WIP, and transports it to a nearby Honeywell Specialty Chemicals manufacturing plant. There, it is converted to fuel for various screw compressors. The 23-mile pipeline used to transport the LFG is the longest in the world used for this purpose. The landfill is one of the largest in the eastern United States, and the gas collected replaces approximately 15 percent of the natural gas used by the manufacturer. The project was named the Landfill Methane Outreach Program's 2004 Project of the Year, and Honeywell was given the

Governor's Environmental Excellence Award, a prize given annually to companies that employ environmentally sensitive practices.

A project in Lorton, Virginia, uses LFG to fuel on-site tube heaters at the I-95 Landfill, which has about 18.07 million tons of WIP. The gas is collected and converted for use in the on-site heaters that warm the facility. Fairfax County contributes to the funding and operation of the project. Another project, located at the same landfill converts gas into fuel for a sludge incinerator at a nearby Wastewater Treatment Plant. Landfill Energy Systems has partnered with the landfill in order to fund this project.

Finally, a project in Lynchburg, Virginia, uses emissions collected from the 2.5 million tons WIP from the Lynchburg City Landfill to fuel a boiler at the Rock Tenn Paper Company. Enerdyne Power Systems is a partner in this project.

West Virginia

Facility	Recovered Gas Offsets or Is Equal To:			
	Used Barrels of Oil	Acres of Forest	Vehicles Removed from the Road	Heated Homes
Greenbrier County Landfill Project	44,700	5,200	3,700	11,500

Although West Virginia is the only SLC state lacking a LFG collection project, there are several prospective sites for planned projects in the state. One of these, the Greenbrier County Landfill Project, if funded, is expected to be operational in 2008. The project was featured at the EPA's Landfill Methane Outreach Program's 2007 Project Expo. It would utilize the 780,000 tons of WIP at the 180-acre Greenbrier County Landfill, which has been collecting waste since 1976. Potential users of the harvested gas include: the West Virginia Department of Transportation, Anthony Correctional Center, AmeriGas (a propane production company), and Lewisburg Processing (a food processing plant), all of which are within a 5.5-mile radius of the landfill. Start-up of the project would create West Virginia's first LFG collection and use program.

Conclusion

In addition to these projects in the 16 SLC states, other projects throughout the country and world have demonstrated the ability to cheaply, safely and effectively collect and process methane gas from landfills. One of the most recent and innovative projects is one funded and operated by Prometheus Energy, which opened a plant in January 2007 that converts methane gas to liquid natural gas (LNG). The project is located in Orange County, California, uses gas emitted from the 379-acre Bowerman Landfill in Orange County, California, and is the first in the world to use methane to produce LNG.

An example of a foreign country that has made great strides in managing large amounts of public waste is Mexico, where methane emissions from landfills contribute about 10 percent of the total anthropogenic greenhouse gases produced in the country. In recent years, there has been a significant push for methane capture projects. The Metropolitan Solid Waste Processing System LFG Energy Project, in Monterrey, Mexico, is an example of a successful joint effort between city government and local business interests to turn LFG into electricity. The electricity produced by this project is used to help run the city transit system and fuel street lamps at night, and provides enough electricity to light more than 15,000 homes. Monterrey is a city of approximately 4 million people and has a daily disposal of about 4,500 tons of municipal solid waste. The $12 million project is partly funded by a $5 million grant from the Global Environment Facility, and it meets approximately 80 percent of Monterrey's public electricity needs. Many other Mexican cities are investigating similar opportunities.[33]

The United Nations has various projects throughout the world focusing on methane release and recovery, the most notable of which is a program in China facilitated by the United Nations Division for Sustainable Development. The project, which began in 1996, helps establish programs in China to combat global warming through the capture of LFG, which is then used for fuel or electricity generation.

According to the EPA, there are an estimated 600 economically viable sites in the United States for the development of LFG recovery projects. The potential electrical output for these sites is about 1,500 megawatts.[34] They operate under the Criteria for Municipal Solid Waste Landfills, a portion of the 1991 Resource Conservation and Recovery Act. Landfills operating after 1991 must be capped to minimize surface emissions. Larger landfills (those that have a capacity of 2.5 millions tons) are required to combust much of the gas emitted and, therefore, landfill-gas-to-fuel projects have become a practical alternative to simply burning off excess emissions. As stated earlier, the United States contributes more than 25 percent of all global methane emissions. China is second at 11 percent.[35]

Smaller landfills (ones with less than 3 million tons of solid WIP) often are overlooked as candidates for LFG recovery projects, due to their small output potential. In many cases these landfills are ideal applicants for such programs. One of the barriers that is difficult for smaller landfills to overcome is access to large markets. Regardless of the size of the landfill, there must be a market for a project to be successful. Supplying a local fuel source is the most advantageous aspect of a smaller LFG project. Smaller landfill operations are ideal for supplying fuel to small buildings, greenhouses, leachate evaporators, and other such operations.

The use of microturbines, which are typically powered by natural gas, is becoming increasingly popular for smaller landfills. Microturbines, like regular turbines, can be converted to operate on LFG. They differ from traditional turbines in that they are smaller and spin at much higher speeds. Also, microturbines burn cleaner than other reciprocating engines and are capable of combusting LFG with lower methane content. They are becoming increasingly

reliable and efficient, and have been a good option for smaller landfills that do not produce enough gas to significantly fuel traditional turbines.[36]

There are various federal incentive programs for LFG collection projects. One is the Renewable Energy Production Incentive, which was established under the Energy Policy Act of 1992. It provides cash subsidies on a per-kilowatt-hour basis for LFG projects. The U.S. Department of Energy makes these incentive payments for up to 10 fiscal years of operation. This program must be reauthorized in 2013, and the incentives can be readjusted by Congress at any time. The qualified facilities certification, a portion of the National Energy Act of 1978, focused on encouraging energy conservation and security, is granted by the Federal Energy Regulatory Commission. The program requires certain utilities to purchase electricity from "qualified facilities," such as landfill-gas-to-energy projects. Qualified facilities must maintain certain standards in order to be eligible for such preferential benefits. Finally, certain projects can qualify for a federal tax credit under Section 29 of the Internal Revenue Service's tax code, which provides incentives for the sale of LFG to an "unrelated third party." Although Congress has renewed this provision several times since its inception in 1979, it requires further reauthorization.[37]

In addition to these federal incentives, most SLC states have laws that provide incentives for alternative fuels; however, many of the laws do not extend to LFG collection projects. As mentioned in each state section, there are several states that do provide such incentives. It is advantageous for states to investigate the benefit of legislation that establishes incentives for LFG collection projects, or to expand existing alternative fuel laws to include these projects. The innovative use of this already-present fuel source can lead to diminished reliance on traditional fuel sources, and greater energy independence for the United States as a whole.

The advantages of LFG collection projects include the destruction of methane; the offset of non-renewable fuels, such as natural gas, oil and coal; cost savings from such supplements; reduction of local air and water pollution; and the creation of jobs and the stimulation of local and state economies. These advantages can produce significant results in states, particularly during a time when the future of the air and water conditions is of great concern; anxiety about public health is at the forefront of civic discussion; energy demands continue to increase as do energy costs; employment resources are limited; and economic stability is unpredictable. Landfill gas has provided great opportunities for SLC states that move beyond merely meeting energy needs, and further opportunities should be explored.

Acknowledgements

For a number of years the Energy and Environment Committee of the Southern Legislative Conference (SLC), currently chaired by Representative Ron Peters, Oklahoma, has been examining Southern states' policies regarding alternative fuel sources. This Regional Resource investigates the various projects in the 16 SLC member states that utilize methane from LFG as a substitute for conventional sources of energy.

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This report was prepared by Jeremy Williams, policy analyst for the Southern Legislative Conference of The Council of State Governments, under the chairmanship of Representative Julia C. Howard, North Carolina.

Endnotes

[1] Methane to Markets, *Landfill Methane Recovery and Use Opportunities*, http://www.methanetomarkets.org/landfills/landfills-bkgrd.htm.

[2] The five largest categories of anthropogenic greenhouse gases, by volume of emissions, are: (1) CO_2 emissions from fossil fuels; (2) methane; (3) nitrous oxide; (4) other CO_2 emissions; and (5) hydrofluorocarbins (used in air conditioning and refrigeration), perflurorocarbins (used in aluminum production), and SF4 (used as an insulator for electricity transportation).

[3] "Greenhouse Gases, Climate Change, and Energy," National Energy Information Center, Energy Information Administration, (Washington, DC, April, 2004).

[4] Methane to Markets, *Methane Reduction Benefits*, http://www.methanetomarkets.org/about/methane.htm.

[5] Christopher Joyce, "In a Cow's Stomach, Novel Approach to Warming," National Public Radio, July, 2007.

[6] Atmospheric lifetime for other greenhouse gases: carbon dioxide = 50 to 200 years; nitrous oxide = ~114 years; hexafluorocarbins = ~260 years; sulfur hexafluoride = ~3,200 years; and perflurorocarbins = as long as 50,000 years.

[7] Environmental Protection Agency, *Landfill Gas Energy: Fueling the Economy and a Sustainable Energy Future While Improving the Environment*.

[8] Environmental Protection Agency, *Methane: Sources and Emissions*, http://www.epa.gov/methane/sources.html (April, 2006).

[9] "Methane Hydrates," in *ORLN Reporter, Number 16*, Oak Ridge National Laboratory, U.S. Department of Energy, (Oak Ridge, TN: June, 2000), p1-2.

[10] Christopher Joyce, "In a Cow's Stomach, Novel Approach to Warming," National Public Radio, July, 2007.

[11] Environmental Protection Agency, *Methane: Sources and Emissions*, http://www.epa.gov/methane/sources.html (April, 2006).

[12] *Ibid.*

[13] Methane to Markets, *Landfill Methane Recovery and Use Opportunities*, http://www.methanetomarkets.org/landfills/landfills-bkgrd.htm.

[14] Methane: Sources, Sinks and Science, Greenhouse Gas Online, http://www.ghgonline.org/methanelandfill.htm

[15] Office of Air and Radiation, Environmental Protection Agency, *Adapting Boilers to Utilize Landfill Gas: Feasible and Cost-Effective*, (January, 2001).

[16] Daniel Gaul, *U.S. Natural Gas Imports and Exports: Issues and Trends 2005*, Office of Oil and Gas Imports, Energy Information Administration (February, 2005).

[17] Environmental Protection Agency, *Methane*, http://www.epa.gov/methane/sources.html

[18] Environmental Protection Agency, "Frequently Asked Questions About Landfill Gas and How It Affects Public Health, Safety, and the Environment, (October 2006), p.2.

[19] The other four categories are curbing sulfur hexafluoride, planting trees, reducing methane emissions from manure, and increasing energy efficiency in buildings.

[20] Environmental Protection Agency, *Landfill Gas Energy: Fueling the Economy and a Sustainable Energy Future While Improving the Environment*.

[21] One million tons of waste-in-place are equal to the generation of 1.1 megawatts a year, and is equivalent to: 9,600 cars taken off the road; or 13,000 acres of forest planted; or 210 railcars of coal not used; or 100,000 barrels of oil not used. Three million tons of waste-in-place is equivalent to: 32,000 cars taken off the road; or 44,000 acres of forests planted; or 720 railcars of coal not used; or 340,000 barrels of oil not used.

[22] The North Carolina Solar Center, *Incentives for Renewables and Efficiency*, http://www.ncsc.ncsu.edu.

[23] *Ibid.*

[24] Fellin, Kevin, Mike Cuccinello, and Becky Cheadle, "Leachate Recirculation," in Groundwater Pollution Primer, Civil Engineering Department, Virginia Polytechnic Institute, 1994.

[25] Birchler, Deborah R., Mark W. Milke, A. Leigh Marks, and Richard G. Luthy, "Landfill Leachate Treatment by Evaporation," in *Journal of Environmental Engineering*, Volume 120, Issue 5, (September 1994), pp. 1109-1131.

[26] The North Carolina Solar Center, *Incentives for Renewables and Efficiency*, http://www.ncsc.ncsu.edu.

[27] *Ibid.*

[28] *Ibid.*

[29] *Ibid.*

[30] *Ibid.*

[31] *Ibid.*

[32] *Ibid.*

[33] Methane to Markets, *Landfill Methane Recovery and Use Opportunities*, http://www.methanetomarkets.org/landfills/landfills-bkgrd.htm.

[34] Environmental Protection Agency, *Landfill Gas Energy: Fueling the Economy and a Sustainable Energy Future While Improving the Environment*.

[35] Chinese carbon emissions are escalating at frightening levels. China may soon pass the United States as the largest emitter of greenhouse gases. Coal-fired power plants in China are far less efficient than the ones in the United States, consuming approximately twice as much coal per kilowatt produced. Russia is third in the world for greenhouse gas emissions, contributing approximately 5 percent globally. Methane to Markets, *Landfill Methane Recovery and Use Opportunities*, http://www.methanetomarkets.org/landfills/landfills-bkgrd.htm.

[36] Microturbines can combust landfill gas with as low as 30 percent to 35 percent methane, whereas traditional turbines require about 50 percent of the landfill gas to be methane.

[37] The United States Environmental Protection Agency, "A Primer on Developing Florida's Landfill Gas-to-Energy Potential," May 2000.

[Landfill Gas to Fuel]

What are landfill-gas-to-fuel projects?

Landfill gas (LFG), produced from decomposing matter stored in landfills, is composed of various greenhouse gases. One of these gases is methane, the second largest of the human-related greenhouse gas emissions in the world (subsequent only to carbon dioxide emitted from fossil fuels). In 2006, U.S. residents, businesses, and institutions produced more than 251 million tons of metric solid waste, most of which was deposited in the more than 1,700 landfills located in the country. Since the 1970s, the LFG recovery projects have existed in order to capture and use this valuable, and otherwise potentially hazardous, gas. According to the U.S. Environmental Protection Agency (EPA), as of December 2006, there were approximately 425 LFG recovery projects operating in 43 states. These sites supply at least 74 billion cubic feet of LFG to end users and generate approximately 10 billion kilowatt hours of electricity every year. The EPA also estimates that the environmental benefits and energy savings from these projects are equivalent to annually: planting 19 million acres of forest; supplementing the consumption of 150 million barrels of oil; eliminating the carbon dioxide emissions from 14 million cars; or offsetting the use of 325,000 railcars full of coal.

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