The case for waste to energy:

Utilizing low-Btu reciprocating gas engine generators

> White paper
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Synopsis

With the development of large reciprocating generator sets that can run reliably on alternative fuels such as low-Btu (i.e. dilute) methane, landfills, waste treatment plants, coal mining facilities and other sources of waste fuel now have a way to harness these "free" energy sources. Low-Btu reciprocating generator sets use proven technology to produce significant amounts of power from fuels that would otherwise be vented to the atmosphere, including methane, a "greenhouse gas" that has been implicated in global warming. This paper outlines the process for determining waste-to-energy site suitability, reviews the maintenance issues and technology answers related to contaminants often found in methane, and cites several working waste-to-energy installations as examples of installed waste-to-energy applications.

Methane's vast global potential

While the exploitation of methane gas for power production from municipal landfills, waste digesters, coal seams and coal mines has been ongoing for several decades, it has been limited to sites with the most favorable economic conditions. However, developments in recent years have focused more attention on this valuable and environmentally advantageous energy source:

- Recognition of methane as a potent "greenhouse" gas that may be exacerbating the buildup of heat in Earth's atmosphere.
- Recognition of naturally occurring methane and sewage/landfill methane as a valuable energy resource that can be converted into usable electricity, thereby offsetting some uses of coal and oil for electric power generation.
- Development of reciprocating engine generator systems that are especially designed to burn dilute methane gas mixtures while mitigating some of the maintenance and engine wear issues that have complicated earlier applications.

Globally, methane from landfills, sewage treatment plants and coal mines represents a vast natural resource that can be economically converted to usable electricity.

In Europe alone, the European Commission estimates that landfills there produce upwards of 94 billion cubic meters of methane each year. In the US, the EPA has estimated that landfills could provide more than two quadrillion Btus of energy per year. Currently in the US, there are approximately 400 operational landfill-to-energy projects and another 600 candidate landfills suitable for energy production, according to the EPA's Landfill Methane Outreach Program.

Methane from coal beds and mines represents another source to be tapped for energy production. In the US alone, estimates of methane production from coal beds amount to 37 billion cubic meters per year.

The expanding role of reciprocating engine generators

Reciprocating engine generator systems are far and away the most popular technology being employed today for producing electricity from natural and man-made sources of methane gas. While combustion turbines are the second most popular technology for harnessing landfill methane, reciprocating engine generators outnumber turbines and other methods by about three times according to the US EPA (Environmental Protection Agency). Some of the reasons that reciprocating engine generators dominate the existing applications are:

- The gaseous fueled reciprocating engine is a mature technology with a number of global manufacturers and an efficient supply and service infrastructure.
- New low-Btu engine designs are able to operate at full rated horsepower with a dilute mixture of only 40 percent methane and above, and they can operate at a slightly derated output with dilutions of only 30 - 40 percent methane.
- Reciprocating engine generator technology is significantly less expensive on an installed cost-per-kilowatt basis than combustion turbine technology.
- While not totally immune, reciprocating engine generators are more tolerant of impurities and contaminants in methane from landfills and coal seams — such as water vapor, ammonia, sulfur and siloxanes.
- Reciprocating engine generators operate at higher electrical efficiencies than turbines and require less complicated methane collection and pressurizing systems. While some other technologies such as Stirling cycle engines, fuel cells and organic Rankin cycle engines also operate at high efficiencies, and show some tolerance to siloxanes, they have been limited to experimental sites due to their high initial costs.
- Reciprocating engines operating on methane have been successful in meeting emissions regulations without exhaust aftertreatment.

Determining site suitability

The usual starting point in deciding whether a particular landfill or methane source is suitable for waste-to-energy production is a gas analysis. This analysis will not only reveal the concentration and volume potential of the methane, it will also identify the various possible contaminants in the gas that may require pretreatment or increase engine maintenance requirements. See Figure 1.

	ppm	molecular weight	constant	ppm
H_2S	15	34	22.4	23
Si	20	28	22.4	25
NOx	150	46	22.4	308
Cl	20	70.91	22.4	63
Fl	1.5	37.99	22.4	3

	mg/Nm^3	molecular weight	constant	mg/Nm^3
H_2S	1000	34	22.4	659
Si	20	28	22.4	16
NOx	21	46	22.4	10
Cl		70.91	22.4	0
Fl		37.99	22.4	0

Figure 1: A typical landfill gas analysis showing concentrations of the contaminants hydrogen sulfide, silicon, nitrogen oxide, chlorine and fluorine in parts per million and milligrams per cubic meter.

If the level of methane concentration is 45 percent or above, then a reciprocating engine generator designed to run on dilute methane can be expected to generate its full nameplate power output. If the methane concentration drops to between 30 and 40 percent, the engine-generator will be capable of producing something less than full power.

The approximate volume of gas required by a typical low-Btu engine generator system is expressed as:

CH_4 Volume = 0.28 cubic meters/hour per kWe x (100 ÷ CH_4%)

This formula is not precise because it is based on pipeline-quality natural gas, and engine efficiency falls as the percentage of non-combustible components in the fuel gas increase. However, it allows a quick assessment of the gas volume needed for any given engine size. When the project appears to be moving forward, specific software programs are used to obtain the actual heating value of the gas. This allows the determination of the actual engine efficiency and the actual volume of gas required. These figures are used to determine the detailed design of the gas delivery system (wells, pumps, filtering and pretreatment).

Contaminants determine maintenance intervals, costs

Considerable time is spent in analyzing the contaminants in the landfill gas, because the volume and makeup of the contaminants have implications for the frequency and extent of engine maintenance schedules. The purpose of the analysis is to clarify economic risks and to share this information with all the parties involved in the project.

The gas must be analyzed on a regular (weekly) basis, and the results shared with all the parties. As the contaminant levels change over time, associated operating costs will also change. The agreement between the parties must define who is financially responsible for changes in operating or maintenance costs when the gas content changes.

Typical contaminants in landfill and coal bed methane include:

- *Silicon* (in the form of siloxanes). When present in landfill gas, siloxanes can plate out on the internal surfaces of the engine's combustion chamber as silicates to a thickness of up to several millimeters. Silicon also enters the lubricating oil causing high wear rates. Siloxane presents a serious maintenance problem when present in the gas stream.
- *Sulfur* (in the form of hydrogen sulfide). When present in high concentrations, it will deposit in the engine, contaminate the lubricating oil and interfere with catalyst systems in the exhaust system (if used).
- *Ammonia*. Common in sewage treatment methane and some landfills, ammonia will corrode certain metals, such as copper in engine cooling systems or bearings.
- *Other contaminants* such as water vapor, particulates, halogens and acids will contaminate engine-lubricating oil. They vary with the types of materials in the landfill.

Low-Btu engines from Cummins Power Generation are designed to be tolerant of many of the typical contaminants found in landfill gas — especially siloxane, ammonia and acids. Since Cummins Power Generation power systems are compliant with current UK emissions regulations without the need for catalytic exhaust aftertreatment systems, sulfur content of the methane does not usually present a serious maintenance problem.

To combat problems that may arise from contaminants, Cummins Power Generation has developed several technologies that help to minimize maintenance and engine overhauls. These technologies include:

- Patented carbon cutting ring – The Cummins low-Btu engine used in landfill applications has a special floating "carbon cutting ring" inset at the top of the cylinder wall in each combustion chamber. The ring serves to break up deposits of carbon and silicates, extending the time between major engine overhauls and rendering the engine less prone to siloxane problems than other designs.
- FCD (ferrous cast ductile) cast iron pistons – Cummins uses FCD cast iron pistons in its low-Btu engines for extended durability when operating on contaminated landfill gas. They are significantly more durable than aluminum alloy pistons.
- Bearing materials – The engine bearings are manufactured from materials that are less susceptible to corrosion from ammonia and acids in the gas stream.
- Charge air cooler – Normally made of copper for the best heat conduction, the vulnerable materials are coated with a phenolic resin to protect them from corrosion. In extremely corrosive environments, the copper may be replaced with stainless steel.
- Engine-lubricating oil – The lubricating oil is generally designed to be more alkaline than typical engine oil to extend the time between oil changes. In general, the lubricating oil is specifically designed for each application, depending on the nature and quantity of contaminants in the gas stream.

Viridor municipal landfill — Edinburgh, Scotland

Salto del Negro garbage digester —
Las Palmas de Gran Canaria, Canary Islands

Moronbah coal seam methane power plant —
Queensland, Australia

Landfill, coal seam and digester gas projects

Cummins Power Generation has been involved in a number of waste-to-energy projects in the US, the UK and elsewhere in the world. Three recent projects illustrate how the methane from a landfill, a coal seam and a garbage digester have been put to useful purposes.

Viridor landfill project produces electricity

Viridor Waste Management, one of the UK's largest operators of municipal landfills, manages a 193-acre site east of Edinburgh, Scotland. Viridor uses two low-Btu gas generator sets from Cummins Power Generation to produce 3.5 MW of electricity from the methane created by decaying rubbish. As the landfill grows and methane production increases, two additional generator sets will be installed to produce a total of 7 MW.

Canary Islands garbage digester earns biogas-derived electricity premium

The Salto del Negro municipal waste treatment plant in the Canary Islands processes garbage collected from Las Palmas de Gran Canaria, a city of 380,000. Some of the waste is processed in a digester which produces methane gas. The gas is used, in turn to fuel a pair of generators from Cummins Power Generation that produce both electricity and heat in a combined heat and power (CHP) system.

Australian coal seam methane powers local grid

In Moronbah, Queensland, methane from a large coal deposit is being collected, processed and piped to the city of Townsville farther up the Australian coast. To power the processing plant, Cummins Power Generation supplied a 12 MW turnkey power station to Ergon Energy. The Moranbah generating plant produces electrical energy for its own coal processing facility and sells excess power to the local grid.

About The Author

Keith Packham is Gas Applications Manager for Cummins Power Generation, and provides expert technical advice and support to the global Energy Solutions Business team on the design, installation and operation of gas fuelled energy plants. He has been involved with the design, installation, maintenance, and operational aspects of combined heat and power (CHP) plants, boiler plants for steam or hot water, power generation and distribution, refrigeration, water and effluent treatment plants and their optimum performance. He holds a bachelor's degree in Energy Engineering from Southbank University in England.

Conclusions

Waste-to-energy projects that utilize methane from landfills, waste digesters and coal beds are generating a significant amount of electric energy for global customers, thus displacing energy that is generated from non-renewable fossil sources that produce carbon dioxide and contribute to global warming. In addition, by utilizing methane for energy production, these systems eliminate emissions of greenhouse gas that is at least 20 times more powerful than carbon dioxide in promoting global warming. The vast majority of waste-to-energy projects use low-Btu reciprocating engine generators to produce electricity from methane. These engine-generator systems have proven to be environmentally clean, reliable, durable and economical in a wide variety of landfill, garbage digester and coal bed methane projects.

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