4.1.3 ELECTRICITY-GENERATION TECHNOLOGIES FOR LANDFILL GAS

Technology Description

Several emerging alternative electricity-generating technologies have significant potential for landfill gas. *Fuel cells* and *microturbines* are technologies that are available in small incremental capacities, have short lead times from planning to construction, and have lower air emissions than other, larger-scale, generation technologies. The modularity of these technologies makes them ideal for use on landfill gas; by adding or removing units, project size can be adjusted to match landfill gas production. *Stirling-Cycle engines* – closed-cycle "hot air" engines – are adaptable for use with landfill gas, are highly efficient, and have low emissions as compared to reciprocating engines. The *Organic Rankine Cycle (ORC)* engine is a process that uses an organic fluid (rather than steam) in a closed cycle to convert thermal energy, such as an engine or flare burning landfill gas into mechanical energy resulting in essentially no air emissions. The ORC may represent a technically feasible alternative for electrical generation using landfill gas.

Three 30-kW microturbines are in use at a landfill in Burbank, California, to generate electricity.

System Concepts

- Fuel cells generate electricity through an electrochemical process in which the energy stored in a fuel is converted directly into electricity, thus avoiding the need for combustion. These units can run on hydrogen that is produced from the methane content in landfill gas and use oxygen from the ambient air. Landfill gas cleanup is an important issue as fuel cells employ catalysts that could be fouled by trace compounds in landfill gas.
- The microturbine is a derivative of the much larger combustion turbines employed in the electric power and aviation industries. Microturbines spin at much faster speeds than traditional combustion turbines.
- Both fuel cells and microturbines generate a significant amount of thermal energy that can be easily captured for use (i.e., hot water/steam), thus increasing the total efficiencies of these units.
- In the Stirling engine, gas is contained in a continuous, closed volume that is divided into hot and cold regions. The size of the volume is periodically varied to compress and expand the gas. Heating and cooling are accomplished by periodically transferring working gas between the hot and cold regions. Since the engine derives its heat from an external source, almost any type of fuel (e.g., landfill gas) or combustible material can be used.
- The Organic Rankine Cycle (ORC) engine is a process that uses fluid in a closed cycle to convert thermal energy, such as a engine or flare burning landfill gas, into mechanical energy (e.g., electricity).

Representative Technologies

- Microturbines currently on the market use air bearings rather than traditional mechanical bearings in order to reduce wear. Combustion air and fuel are mixed in a combustor section, and the release of heat causes the expansion of the gas. Hot gas is sent through a gas turbine that is connected to a generator. Units are normally equipped with a recuperator that heats combustion air using turbine exhaust gas in order to increase the unit's overall efficiency. Combustion air is compressed using a compressor that is driven by the gas turbine. Use of landfill gas requires gas compression.

Technology Status/Applications

- Several types of fuel cells using different electrolytes are either available or under development. The four basic electrolyte types are: (1) phosphoric acid, which is commercially available and has been demonstrated commercially on landfill gas; (2) molten carbonate, which has also shown promise for landfill gas use; (3) solid oxide; and (4) proton exchange membrane (polymer-membrane).
- The microturbine is a recently commercialized technology. Sixteen microturbine projects (10 megawatts) are

operational, and at least one additional project is under construction.

- Since January 2003, the first successful demonstrations of 2-25 kW and 10-25 kW Stirling-Cycle engines using landfill gas are operational at two landfills in Michigan. A Stirling engine also became operational in March 2005 at a landfill in Texas to supply electricity to a biodiesel project.
- Since 2004, two Organic Rankine Cycle demonstration projects have been operational at landfills in Texas and Illinois. The project in Austin, Texas, captures waste heat from a LFG flare and uses it to generate 200 kW of electricity. The Danville, Illinois, project involves exhaust heat recovery from three LFG-fired reciprocating engines to generate 200 kW of electricity.

Current Research, Development, and Demonstration

RD&D Goals

- Evaluate and demonstrate use of landfill gas as a fuel source for fuel cells and appropriate and cost-competitive cleanup technologies.
- Demonstrate long-term performance of microturbines on landfill gas, improve component corrosion protection, and develop larger microturbines.
- Demonstrate Stirling-Cycle and Organic Rankine engines at additional landfills; and evaluate technical (e.g., O&M), economic, and environmental considerations by 2006.

RD&D Challenges

- For fuel cells, developing cleanup technologies for landfill gas that are adequate but not cost prohibitive.
- For microturbines, dealing with potential fouling and failure of the turbine unit from silica or other components in landfill gas, and potential corrosion and excessive wear of components due to constituents found in landfill gas. In addition, microturbines are not currently cost competitive with traditional reciprocating engines. The total cost of power production, based on net power output and assuming retirement of the capital cost during 10 years at an interest rate of 10%, would be $0.07–$0.14/kWh ($0.04-$0.06 for recip. engine).
- High cost to demonstrate Stirling engine and Organic Rankine engine; no commercial-scale units have been designed or demonstrated.
- Continued testing and commercialization of fuel cell and microturbine technologies.
- Technologies/processes to pretreat landfill gas prior to introduction to fuel cells and microturbines.
- Development of larger microturbines (i.e., greater than 75 kW).
- Development of larger Stirling engines and continuing to test Stirling and Organic Rankine Cycle technologies.

RD&D Activities

- EPA-funded phosphoric acid fuel cell demonstration on LFG in California; the same system was also demonstrated in Connecticut. DOE/EPRI funded a molten carbonate fuel cell on LFG; EPA funded a study to evaluate LFG cleanup technologies for use with fuel cells; and a DOE small-business innovative research grant funded a demonstration converting LFG to methane for fuel cell use.
- Three microturbine demonstration projects with landfill gas have been completed since October 1999 – a 75-kW unit in New Mexico and California, and a 30-kW unit in California. In 2000, EPA funded a demonstration of a microturbine on landfill gas in Oregon. In 2001 and 2002, EPA funded two additional microturbine demonstration projects in Virginia and Vermont to test new microturbine technologies.
- Today, one manufacturer is developing commercially viable Stirling engines versions for landfill application (up to 250 kW). One manufacturer is developing a commercially viable Organic Rankine engine for landfill application (200 kW).
- Since 1999, the Salt River Project (led by DOE and a municipal utility located in Phoenix, Arizona) is demonstrating the operation of the first thermal hybrid-electric sundish. This technology combines solar thermal heliostats and a Stirling cycle engine using landfill gas (dual “fuel” Stirling cycle engine).

Recent Progress
• A 200 kW phosphoric acid fuel cell is currently operating on landfill gas from the Braintree, Massachusetts, landfill. • Microturbines have been demonstrated to operate on landfill gas with a low methane content, and have demonstrated NO_x emissions less than one-tenth those of the best performing reciprocating engines • Demonstration of the first thermal hybrid-electric sundish (combines solar and Stirling cycle engine using landfill gas) has been running successfully since 1999. • Since January 2003, the first successful demonstrations of 2-25 kW and 10-25 kW Stirling cycle engines using landfill gas are operational at two landfills in Michigan.
Commercialization and Deployment Activities
• Phosphoric acid fuel cells are commercially available today, and many are installed worldwide. Most are using fuels other than landfill gas, but this type of fuel cell has been successfully demonstrated on landfill gas. Molten carbonate fuel cells have been operated on landfill gas – as well as a variety of other fuels – and this type of fuel cell looks particularly promising for landfill gas application due to its tolerance of CO_2 . • At least two companies manufacture and sell microturbines for landfill gas applications (30 kW – 200 kW); 16 commercial microturbine projects (10 megawatts) fired by landfill gas have been operational since January 2002. • Several landfill gas pilot-plant studies have been conducted for Stirling technology, and two ORC pilot projects are operational. **Market Context** • A market for these technologies exists wherever there is a need for electricity generation capacity. Hundreds of thousands of landfills and open dumps exist worldwide, all of which generate some amount of methane that could be used as a local energy resource for communities. Efforts to improve the cost effectiveness of these technologies will allow for greater landfill market development.