LMOP Workshop: LFG Collection & LFG Energy Technologies

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Introduction

- Goal – convert LFG into a useful energy form
- Technologies include:
  - Power production/cogeneration
  - Direct use of medium-Btu gas
  - Production of high-Btu gas
- Three components of all LFG systems:
  - Gas collection system and flare
  - Gas treatment system
  - Energy recovery system
- The type of technology selected for a project depends on local conditions
Landfill Gas to Energy

How methane gas flows from the landfill and through filters to provide both heat and electricity.
## Technologies for Electricity Generation

<table>
<thead>
<tr>
<th>Project Technology</th>
<th>Number of Projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal Combustion Engines</td>
<td>370</td>
</tr>
<tr>
<td>Gas Turbine</td>
<td>36</td>
</tr>
<tr>
<td>Cogeneration</td>
<td>41</td>
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<tr>
<td>Steam Turbine</td>
<td>15</td>
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<tr>
<td>Microturbine</td>
<td>15</td>
</tr>
<tr>
<td>Combined Cycle</td>
<td>10</td>
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<tr>
<td>Stirling Cycle Engine</td>
<td>2</td>
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</table>
## Technologies for Direct Use

<table>
<thead>
<tr>
<th>Project Technology</th>
<th>Number of Projects</th>
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<tr>
<td>Boiler</td>
<td>61</td>
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<tr>
<td>Direct Thermal</td>
<td>49</td>
</tr>
<tr>
<td>High-Btu</td>
<td>30</td>
</tr>
<tr>
<td>Leachate Evaporation</td>
<td>12</td>
</tr>
<tr>
<td>Greenhouse</td>
<td>5</td>
</tr>
<tr>
<td>Alternative Fuel</td>
<td>5</td>
</tr>
</tbody>
</table>
33 Operational LFG Energy Projects

- 101 megawatts (MW) of electrical generation from 24 LFG energy projects in Texas
- 35 million standard cubic feet per day of LFG is utilized in 9 direct use projects

2 projects under construction:

- Ft. Bend Regional Landfill (highBTU)
- Nelson Gardens LF (electricity)

Over 50 Candidate Landfills in Texas
Gas Collection System and Flare

- Major components:
  - Collection wells and trenches
  - Condensate collection and management system
  - Blower
  - Flare
Collection Wells and Trenches

- Two collection configurations:
  - Vertical wells
  - Horizontal trenches

- System design depends on:
  - Site-specific conditions
  - Timing of installation

- LFG from each well is transported via lateral pipes to a main collection header
Collection Wells and Trenches (cont.)

- Condensate collection
  - Forms when warm gas cools in a pipeline
  - Can impede flow of LFG
- Blower
  - Pulls gas from landfill
  - Size and type depends on system
- Flare
  - Controls emissions during project start-up or downtime
Collection Wells and Trenches (cont.)

- System costs depend on site-specific conditions

- Example:
  - 40 acre site designed for 600 cfm gas flow
  - $25,000/acre or $1,000,000 total
  - $2,350 annual O&M costs/well
  - $4,700 annual O&M costs/flare*

* Based on 2012 cost estimates
Treatment requirements depend on end-use of the LFG:

- Direct use – minimal treatment
- Electricity – treatment to remove contaminants that might damage engines/turbines
- High-Btu – extensive treatment required
LFG Treatment Systems (cont.)

- **Primary treatment**
  - Dewatering and filtration to remove moisture and particulates
  - More common - compression and cooling to remove water vapor and humidity

- **Secondary treatment**
  - Provide much greater gas cleaning
  - Two common contaminants removed include siloxanes and sulfur
Energy Recovery Systems

- Power production/cogeneration
- Direct use of medium-Btu gas
- Production of high-Btu gas
Electricity Generation

- 75% of all LFG energy projects produce electricity
- Common technologies include:
  - Internal combustion engines
  - Gas turbines
  - Microturbines
**Internal Combustion Engines**

- Most common type of technology
- **Advantages**
  - Relatively low cost
  - High efficiency (25-35%)
  - Good size match for many landfills
    - Typical output 800 kW to 3 MW
Examples of available internal combustion engine sizes and corresponding gas flows:

<table>
<thead>
<tr>
<th>Engine Size</th>
<th>Gas Flow (cfm at 50% methane)</th>
</tr>
</thead>
<tbody>
<tr>
<td>540 kW</td>
<td>204</td>
</tr>
<tr>
<td>633 kW</td>
<td>234</td>
</tr>
<tr>
<td>800 kW</td>
<td>350</td>
</tr>
<tr>
<td>1.2 MW</td>
<td>500</td>
</tr>
</tbody>
</table>
Gas Turbines

● More suitable for larger projects
  ■ Typically larger than 5 MW

● Advantages:
  ■ Significant economics of scale
  ■ Resistant to corrosion
  ■ Lower nitrogen oxide emission rates
  ■ Relatively compact with low O&M costs

● Disadvantages:
  ■ Less efficient than IC engines
  ■ Siloxane Removal
Microturbines

- Reasons to select technology:
  - Reduced LFG availability (<300 scfm)
  - Lower LFG methane content (<35%)
  - Lower nitrogen oxide emissions
  - Add and remove units as gas quantities change
  - Ease of interconnection
Microturbines (cont.)

- Treatment typically required:
  - Moisture removal
  - Siloxanes
  - Sulfur

- Sizes include 30, 70 and 250 kW units
  - Larger capacity units should be used if LFG quantities exist

- More expensive on a dollar-per-kW installed capacity basis
# Sample Electricity Generation Costs

<table>
<thead>
<tr>
<th>Technology</th>
<th>Typical Capital Costs ($/kW)*</th>
<th>Typical Annual O&amp;M Costs ($/kW)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal Combustion Engine (&gt;800 kW)</td>
<td>$1,700</td>
<td>$180</td>
</tr>
<tr>
<td>Small Internal Combustion Engine (&lt;1MW)</td>
<td>$2,300</td>
<td>$210</td>
</tr>
<tr>
<td>Gas Turbine (&gt;3MW)</td>
<td>$1,400</td>
<td>$130</td>
</tr>
<tr>
<td>Microturbine (&lt;1MW)</td>
<td>$5,500</td>
<td>$380</td>
</tr>
</tbody>
</table>

* 2010 dollars
Direct Use

- 25% of all LFG energy projects are direct use applications
- LFG is piped to nearby end-user and used in boiler or other industrial process
- Limited treatment is required
- Ideal gas end-user will have a steady gas flow compatible with landfill’s gas flow
Direct Use (cont.)

- Provide LFG to multiple end-users if one ideal end-user is not available
- Using LFG may require equipment modifications
- LFG quality might be improved to avoid equipment modifications
- LFG typically treated to remove siloxanes
Direct Use (cont.)

Boiler

- Most common type of direct use project (over 60 projects operating)
- Minimal LFG treatment required
- Usually requires some modifications to run on LFG
Typical LFG Flows Based on Landfill Size

<table>
<thead>
<tr>
<th>Landfill Size (metric tons WIP)</th>
<th>LFG Output (MMBtu/yr)</th>
<th>Steam Flow Potential (lbs/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,000,000</td>
<td>100,000</td>
<td>10,000</td>
</tr>
<tr>
<td>5,000,000</td>
<td>450,000</td>
<td>45,000</td>
</tr>
<tr>
<td>10,000,000</td>
<td>850,000</td>
<td>85,000</td>
</tr>
</tbody>
</table>
Direct Use (cont.)

Leachate Evaporation

- 12 operational projects
- Good option if leachate disposal is unavailable or expensive
- Typical evaporator size 10,000 to 30,000 gallons per day
- Costs:
  - Capital
    $300,000 - $500,000
  - Annual O&M
    $70,000 - $95,000
Direct Use (cont.)

Greenhouses

- 5 projects in operation
- LFG used for heating and hot water production in hydroponic plant culture
- Costs will vary
Direct Use (cont.)

Artisan Studios

- Used in energy-intensive activities:
  - Glass-blowing
  - Metalworking
  - Pottery kilns

- Can be very successful if community backs project

- Small LFG flows and relatively inexpensive
High-Btu Gas Production

- Refers to increasing the CH$_4$ content of the gas and decreasing CO$_2$
- Common uses of high-Btu gas:
  - Injection into natural gas pipeline
  - Creation of vehicle fuel (CNG, LNG)
- Typically more expensive
- Process may achieve economies of scale for larger projects
High-Btu Gas Production (cont.)

• Three common methods for producing high-Btu gas:
  ■ Amine scrubbing
  ■ Molecular sieve (or PSA)
  ■ Membrane separation

• Methods focus on removing CO$_2$

• O$_2$ and N are best controlled by proper collection system operation
Amine Scrubbing

- Selexol is the most common amine used
- Process includes:
  - LFG compression
  - Moisture removal using refrigeration
  - H$_2$S removal in solid media bed
  - NMOC removal via Selexol absorber
  - CO$_2$ removal via secondary Selexol absorber
Molecular Sieve

- Employs compression, moisture removal and H$_2$S removal similar to amine scrubbing
- Utilizes activated carbon and molecular sieve for NMOC and CO$_2$ removal
Membrane Separation

- Employs compression, moisture removal and H$_2$S removal similar to amine scrubbing
- Utilizes activated carbon to remove NMOCs
- Uses membranes to remove CO$_2$
CNG Production

- Membrane separation and molecular sieve technology used to produce CNG
- 100 cfm of LFG = 440 diesel gallons
LNG Production

- LNG is produced using conventional natural gas liquefaction technology
- Conditions:
  - Little to no CO₂ present
  - Systems are customized and generally on larger scales
- O₂ and N removal are essential
Selection of Technology

- Primary consideration: projected expense vs. potential revenue
- Sale of medium-Btu gas is often the simplest and most cost-effective
- Electricity projects may make more sense if:
  - No near-by energy user
  - Additional revenue sources are available (RECs, carbon credits)
- High-Btu may be best if enough gas
Selection of Technology (cont.)

- Considerations in selecting the right technology for electricity generation:
  - Gas recoverability for at least 10 years
  - Gas quality
  - Need for heat or steam – might consider a CHP project
  - State and local air quality regulations

- Remember each project is site-specific and there are other factors to consider.
Thank you!

Questions?