Landfill Gas to Energy

TDEC Landfill Operators Training

October 7 & 14, 2010
Oak Ridge & Jackson, TN

Presenters:
Stacey A. Smith, P.E., RSG
Jo House, P.G., P.E., House Engineering
Landfill Gas to Energy

- Creation and Capture
- Collection and Control
- Conversion
- Cash, Credits, and Carbon
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Creation and Capture

Modeling

- EPA’s LandGEM Model
- Proprietary Stochiometric Models

\[ Q_{CH_4} = \sum_{i=1}^{n} \sum_{j=0.1}^{1} k L_i \left( \frac{M_i}{10} \right) e^{-kt_{i,j}} \]

- Factors
  - Waste acceptance rates;
  - CH\textsubscript{4} generation rate constant (k);
  - Potential CH\textsubscript{4} generation capacity (Lo); and
  - Collection Efficiency.
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Example County Landfill LFG Generation Curve

- Untlined North-Generated LFG
- Untlined North-Collected LFG
- Lined South-Generated LFG
- Lined South-Collected LFG
- Combined North & South Generated
- Combined North & South-Collected

[Graph showing LFG flow rates from 1987 to 2009]
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- Collection and Control
  - Design Factors
  - Collection Alternatives
  - Wellhead Control
  - System Vacuum
  - Efficiency and Maximization
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- Design Factors by the New Source Performance Standards
  - depth of refuse;
  - refuse gas generation rates and flow characteristics;
  - cover properties;
  - gas system expandability;
  - leachate and condensate management;
  - accessibility;
  - compatibility with filling operations;
  - integration with closure end use;
  - air intrusion control;
  - corrosion resistance;
  - fill settlement; and
  - resistance to the refuse decomposition heat.
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• Collection Alternatives
  – Vertical Extraction Wells
  – Horizontal Trenches
  – Vertical Caissons
  – Strip Collectors
  – Manifold System
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- Vertical Well
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- Horizontal Trench
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- Caissons
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• Strip Collector
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- Manifold System
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- **Wellhead**
  - gas quality ($\%O_2$, $\%CH_4$);
  - static pressure (vacuum pressure at the well);
  - differential pressure;
  - system pressure;
  - flow; and
  - temperature.
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- System Pressure
  - Dual Phase Flow Design
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- Dual Phase Flow Considerations
  - Landfill Gas
  - Condensate
  - Seasonal
  - Pipe Diameter
  - Slope
  - Flow Direction
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Period when system turns off.

Build up of condensate in system again.

Surging in system called by condensate slugs.

System begins to surge again due to condensate slug.

Shuts valves off to pull condensate slugs out of system.
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- Efficiency and Maximization
  - Coverage (Radius of Influence)
  - Capture (Effects of Final Cover)
  - Moisture (Recirculation, Injection)
  - Waste Stream (Nutrients, Organics, Sludges)
  - Leachate Collection System
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- **Conversion**
  - Electricity
  - Direct Use
    - Medium BTU Projects
    - High BTU Projects
  - Values
    - CH$_4$ Heating Value = 1,013 Btu/Cubic Foot
    - Decatherm = 10 therms
    - Therm = 100,000 Btu (British Thermal Units)
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- Landfill Gas Quality
  - Moisture
  - Particulates
  - Siloxanes (Si)
  - Hydrogen Sulfide (H₂S)
  - Cleaning Systems (NSPS)
    - Compression
    - Dewatering
    - Filtering < 10 microns
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• Direct Use Projects
  • Medium Btu
    • Transportation is key;
    • Volume of gas required;
    • Offset pricing;
  • High Btu
    • Quality is key;
      • < 0.2% \( O_2 \)
      • < 3% \( CO_2 \)
    • Begins at the wellhead;
    • Carbon Dioxide removal;
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- Utility Interconnection
  - TVA is master, No formal program
  - Cities, REA’s, and EMC’s
  - Application
  - Impact Study (System Upgrades)
  - Power Purchase Agreement
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• Generation
  - Jenbacher (320 or 420)
  - Caterpillar (3516 to 3520)
  - Waukesha
  - Cummins
  - Methane Buster (small flows)
    (picture courtesy of KSD Enterprises, Clarksburg, WV)
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- **Cash, Credits, and Carbon**
  - Direct Sale Payments
  - Tax Credits
  - Renewable Energy Credits
  - Grants
  - Carbon Markets
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- Direct Sale Payments
  - What is the Value of the Project?
  - Fuel Offsets
  - Electricity (RPS)
  - Steam
  - Internal Site Use
  - The Value is in the Customer!
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- Renewable Energy Portfolio Standard (RPS)
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• Credits
  – Section 1603/45 Renewable Electricity Production Credit
    • [http://www.epa.gov/lmop/docs/engy_pol.pdf](http://www.epa.gov/lmop/docs/engy_pol.pdf)
    • Approx value of 1.0 cent/kilowatt-hour (kWh) or 30% initial payment
  – Clean Renewable Energy Bonds (CREBS)
    • Provides interest free financing by providing a credit against federal income taxes
  – Tennessee Valley Generation Partners
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- Carbon
  - Voluntary Market
  - Chicago Climate Exchange (CCX)
    - [http://chicagoclimatex.com/](http://chicagoclimatex.com/)
    - Credits are traded on a public exchange. Recent prices around $.10 MTCO2E.
  - Regional Greenhouse Gas Reduction Programs
  - California Climate Action Registry (CCAR)
  - Regional Greenhouse Gas Initiative (RGGI)
  - Brokers and Aggregators
  - Credits verified under stringent Voluntary Carbon Standard (VCS)
    - [http://www.v-c-s.org](http://www.v-c-s.org)
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• Grants
  – Renewable Energy Production Incentive (REPI)
    • Payments of $15/MWh from eligible facilities
    • http://www.eere.energy.gov/repi/
# Landfill Gas to Energy

## Project Costs and Revenue Streams - Year 2011

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost Included</th>
<th>Capital Costs</th>
<th>O&amp;M Costs</th>
<th>Revenue (REC, Carbon Credit, and Electric Value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial LFG Collection</td>
<td></td>
<td>$252,300</td>
<td>$666,308</td>
<td></td>
</tr>
<tr>
<td>Collection System Area (acres)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flare/Blower</td>
<td></td>
<td>$230,800</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engineering / Permitting / Construction (assume 20%)</td>
<td>$179,423</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Subtotal - Collection System</strong></td>
<td>$1,075,830</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LFG Collection Expansion cost per yr²</td>
<td></td>
<td>$35,500</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engineering / Permitting / Construction (assume 20%)</td>
<td>$7,300</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Subtotal - Collection System</strong></td>
<td>$43,800</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Periodic Collection System Costs (1-year increment)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total Project Costs</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## Project Costs and Revenue Streams - Year 2012

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost Included</th>
<th>Carbon Credit Value ($/tonne)</th>
<th>Revenue Stream Availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Tax Position and Credits ³⁄₄ 2012</td>
<td></td>
<td>$3.075</td>
<td>$50,000</td>
</tr>
<tr>
<td><strong>Total Project Costs</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## Project Costs and Revenue Streams - Year 2013

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost Included</th>
<th>Annual Escalator (%) ¹⁻¹</th>
<th>Project Year</th>
<th>Projected Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>LFG Dryer System</td>
<td>$250,000</td>
<td>34.0%</td>
<td>2011</td>
<td>$3,000</td>
</tr>
<tr>
<td>Siloxane removal</td>
<td></td>
<td>6.9%</td>
<td>2013</td>
<td>$3,152</td>
</tr>
<tr>
<td>Sulfur Oxidation</td>
<td></td>
<td>383.0%</td>
<td>2014</td>
<td>$3,231</td>
</tr>
<tr>
<td>Engineering / Permitting / Construction (assume 20%)</td>
<td>$50,000</td>
<td></td>
<td>2015</td>
<td>$3,311</td>
</tr>
<tr>
<td><strong>Subtotal - Treatment System</strong></td>
<td>$350,000</td>
<td></td>
<td>2016</td>
<td>$3,384</td>
</tr>
<tr>
<td>Power Generation Units (⁴⁄₅)</td>
<td></td>
<td></td>
<td>2017</td>
<td>$3,479</td>
</tr>
<tr>
<td>GenSet Unit(s)</td>
<td></td>
<td></td>
<td>2018</td>
<td>$3,566</td>
</tr>
<tr>
<td><strong>Total Project Costs</strong></td>
<td></td>
<td></td>
<td>2019</td>
<td>$3,656</td>
</tr>
<tr>
<td><strong>Total Project Costs</strong></td>
<td></td>
<td></td>
<td>2020</td>
<td>$3,747</td>
</tr>
<tr>
<td><strong>Total Project Costs</strong></td>
<td></td>
<td></td>
<td>2021</td>
<td>$3,834</td>
</tr>
</tbody>
</table>

## Project Costs and Revenue Streams - Year 2012

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost Included</th>
<th>Annual Revenue Streams ($/yr) 2012</th>
<th>Sale of Carbon Credits from gas collected</th>
<th>$59,149</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Project Costs</strong></td>
<td></td>
<td></td>
<td>Sale of RECs from Electricity Generated</td>
<td>$217,881</td>
</tr>
<tr>
<td><strong>Subtotal Electric Generation Facilities</strong></td>
<td>$1,548,153</td>
<td></td>
<td>Value of Power Sales to Utility Cooperative</td>
<td>$239,427</td>
</tr>
<tr>
<td>O&amp;M Costs</td>
<td></td>
<td></td>
<td>Section 1603 Cash Grant in Lieu of Section 45 Tax Credit</td>
<td>$488,571</td>
</tr>
<tr>
<td><strong>Total Project Costs</strong></td>
<td></td>
<td></td>
<td>Value of State Renewable Energy Tax Credit</td>
<td>$90</td>
</tr>
</tbody>
</table>

## Project Costs and Revenue Streams - Year 2012

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost Included</th>
<th>Total Revenue Streams 2012</th>
<th>Other Incentives (grants, etc.)</th>
<th>$90</th>
</tr>
</thead>
</table>

**Highlighted cells represent areas of uncertainty**

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[Image of Richardson Smith Gardner logo]

[Address: 14 N. Boylan Avenue, Raleigh, NC 27603]
Landfill Gas to Energy

• Questions or Observations
Landfill Gas to Energy

- Creation and Capture
  - Generation vs. Collection
- Collection and Control
  - Control at the Wellhead
  - Manage Condensate
- Conversion
  - Location is key
  - Quality must be considered
- Cash, Credits, and Carbon
  - Value vs. Royalty
  - Look at the big picture!