Equipment Considerations for Landfill Gas Generator Sets: Total Cost of Ownership

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Caterpillar Electric Power

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Baltimore, January 2012
What Am I Doing Here?

• One year ago in Baltimore ....
  – Siloxane measurement presentation (SCS)
  – What is the siloxane reading on this LFG sample?

• Several labs .... different results!
  – No wrong answers, just different points of view.
  – Unit conversion nuances / Different test conditions /
    Different standards / Same standard, different insight.

• Hard to compare results without solid
  understanding of measurement techniques.
What Am I Doing Here?

• Somewhat similar scenario for genset data.
• Hard to compare estimates for total cost of ownership in LFGTE projects (5, 10, 20 years)

- How many kWe will this genset deliver at my job site?
- What will be the engine fuel consumption at site?
- What additional equipment does the genset require?
- What assumptions are built into this O&M cost estimate?
Equipment Considerations for LFG Gensets

Agenda

• Equipment Ratings
• Capital Costs
• Efficiency v. Capacity
• Maintenance & Repair Cost
Ratings – Auxiliary Equipment Power

• For diverse technical and commercial reasons, many published kWe ratings do not include the power required to drive REQUIRED equipment
  – Pumps: water, oil
  – Inlet gas compressors
  – Radiator cooling fan

• If not taken into account, this could make the apparent genset kWe capability and efficiency larger than it is.
Ratings – Auxiliary Equipment Example

• Example: Cat gas engine ratings
  – Std. genset: Rating with water pumps (engine-driven)
  – CHP genset: Rating w/o water pumps (electric)
  – All Cat gas gensets rated w/o cooling fan losses (electric)

• CAT CHP genset: 2x electric water pumps consume approximately 30 kWe
  – Jacket water (JW), separate circuit aftercooler (SCAC)
  – Cost to operate: $13,000 to $25,000 per year
Life Cycle Cost & Water Pumps – G3516C

1.7% more power; 27 additional kW

1.7% lower operating costs
Ratings – Power Factor

• Genset kWe ratings depends on p.f. assumed for the load. Higher p.f. = higher kWe rating.

• However, p.f. of the load is site-specific.
  – Classical electrical engineering calculations and genset ratings developed around estimated ‘real-life’ p.f 0.8
  – Modern industrial sites: p.f. between 0.8 and 0.95

• Manufacturers moving to 1.0 p.f. ratings

• Customers need to adjust rating for their p.f.
Electrical Rating - Power Factor

- Caterpillar publishing new gas genset ratings at both 0.8 and 1.0 pf.
- If a 0.8 p.f. rating was not published, a customer could overestimate his annual energy sale revenues by $23,000.

A 1.0 p.f. Offers a 1.4% rating advantage (27 additional kW) over 0.8 p.f.
Compare G3516C
Difference: 0.8 vs. Unity Power Factor

0.8 Power Factor
0.7% more power; 9 additional kW

1.0 (Unity) Power Factor
0.2% lower operating costs
Combined Effect

Scenario 1
• Sell Power to Industry @0.8PF
• Engine Powered Pumps
• Engine Powered Fans

Scenario 2
• Sell Power to Utility @0.95PF
• Electric Pumps (grid power)
• Electric Fan (grid power)
Other Ratings Considerations

• ISO vs. nominal ratings, fuel efficiency
• Ratings w/ no exhaust backpressure
• IEC losses calculations
• Rating listed at ISO rating conditions vs. IEC
• Minimum Methane Number requirements
Capital Cost – Gas Compression Skid

• Some engines require high inlet gas pressures
  – E.g. Cat G3600 family, pre-chamber design, 150psi
  – A gas compression skid is REQUIRED for operation.

• Other gas engines accept low inlet pressures
  – E.g. Cat G3520C requires only 1.5-5 psi LFG
  – Only a simple gas regulator is needed for operation

• A fair comparison of G3612 v. G3520C cost of ownership needs to include the capital and maintenance cost of the gas compression skid.
Capital Cost – Siloxane Treatment

- Higher efficiency engines accept less LFG contaminants than lower efficiency engines.
- Depending on site specifics, high efficiency engines often REQUIRE specialized siloxane removal (gas conditioning skids).
- A fair comparison of cost of ownership needs to include the capital and maintenance cost of the gas conditioning skid.
Efficiency v. Capacity

• **Electrical Efficiency:** % or energy input to the generator set that gets converted to electrical output. (kW)

• **Capacity Factor:** % of time the generator set is in operation and producing ekW. (Operational Availability)

• Both factors play a key role in maximizing the revenues of your power generation project.
Same Capacity, Different Efficiency

<table>
<thead>
<tr>
<th></th>
<th>Unit A</th>
<th>Unit B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gen set kW</td>
<td>1000</td>
<td>1000</td>
</tr>
<tr>
<td>Gas Price $/mmbtu</td>
<td>$2.00</td>
<td>$2.00</td>
</tr>
<tr>
<td>Value of Energy Produced $/MW-hr</td>
<td>$70.00</td>
<td>$70.00</td>
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<tr>
<td>Generator Efficiency</td>
<td>97.0%</td>
<td>97.0%</td>
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<tr>
<td>Engine Heat Rate BTU/min</td>
<td>145,000</td>
<td>135,000</td>
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<tr>
<td>Capacity Factor</td>
<td>96.0%</td>
<td>96.0%</td>
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<tr>
<td>Generator Set Electrical Efficiency</td>
<td>39.2%</td>
<td>42.1%</td>
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<tr>
<td>Fuel Consumed/yr mmbtu</td>
<td>73,163.52</td>
<td>68,117.76</td>
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<tr>
<td>Cost of Fuel/Year</td>
<td>$146,327</td>
<td>$136,236</td>
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<tr>
<td>MW-Hour produced</td>
<td>8,410</td>
<td>8,410</td>
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<tr>
<td>Fuel Cost /MW-hr</td>
<td>$17.4000</td>
<td>$16.2000</td>
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<tr>
<td>Value of Power Produced</td>
<td>$588,672</td>
<td>$588,672</td>
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<tr>
<td>Net Revenue (Fuel Cost vs Power Produced)</td>
<td>$442,345</td>
<td>$452,436</td>
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## Same Efficiency, Different Capacity

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<td>90.0%</td>
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<tr>
<td>Generator Set Electrical Efficiency</td>
<td>42.1%</td>
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<tr>
<td>Fuel Consumed/yr mmbtu</td>
<td>68,117.76</td>
<td>63,860.40</td>
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<tr>
<td>Cost of Fuel/Year</td>
<td>$136,236</td>
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<td>MW-Hour produced</td>
<td>8,410</td>
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<td>Fuel Cost /MW-hr</td>
<td>$16.20</td>
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<td>Value of Power Produced</td>
<td>$588,672</td>
<td>$551,880</td>
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<tr>
<td>Net Revenue (Fuel Cost vs Power Produced)</td>
<td>$452,436</td>
<td>$424,159</td>
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</table>
What affects each factor?

• Efficiency:
  – Product design/technology/quality.
  – Fuel quality.

• Capacity
  – Product design/technology/quality.
  – Service capability
  – Parts Availability.
Maintenance and Repair Considerations

- **Cost Factors**
  - Preventive Maintenance
  - Scheduled Maintenance
  - Unplanned Repairs

- **kWh Production**
  - Parasitic Losses (Pumps / Fans)
  - Capacity Factor (Fuel Availability)
  - Ambient Conditions (Deration)
  - Power Factor (Gen Eff.)
Fuel Quality Impact on M&R Costs

Cost / kWh

Contaminants: Ammonia, Halides, Siloxanes, Hydrogen Sulfide

Assumed Overhaul Schedule (Top End, In Frame, Major)

High Contaminant = 7k, 21k, 35k Hours
Low Contaminant = 18k, 54k, 90k Hours
Fuel Contaminants & Bottom Line

G3520C 1600kW Genset

<table>
<thead>
<tr>
<th></th>
<th>High Contaminant</th>
<th>Low Contaminant</th>
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</thead>
<tbody>
<tr>
<td>Cost</td>
<td>$361,732</td>
<td>$236,039</td>
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<tr>
<td>Revenue</td>
<td>$1,489,729</td>
<td>$1,507,947</td>
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<tr>
<td>Profit</td>
<td>$1,127,977</td>
<td>$1,271,908</td>
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</tbody>
</table>
Repair Risk Management

• Scheduled repairs per service manual intervals

• Predictive Repair Scheduling
  – Valve Recession, Oil Consumption, Fuel Consumption, Exhaust Emissions

<table>
<thead>
<tr>
<th></th>
<th>Cat G3520C HV Low Energy Gas @ 1613 kW, 1200rpm</th>
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</thead>
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<tr>
<td><strong>Average Cost / Revenue Comparison</strong></td>
<td></td>
<td></td>
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<tr>
<td><strong>Per Year</strong></td>
<td>$289,416.97</td>
<td>$246,443.11</td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td><strong>$289,416.97</strong></td>
<td><strong>$246,443.11</strong></td>
</tr>
<tr>
<td><strong>Revenue</strong></td>
<td><strong>$1,338,064.96</strong></td>
<td><strong>$1,343,508.03</strong></td>
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<tr>
<td><strong>Profit</strong></td>
<td><strong>$1,048,647.99</strong></td>
<td><strong>$1,097,064.92</strong></td>
</tr>
</tbody>
</table>
Other Operation, M&R Considerations

• Methodology to schedule engine interventions
  – B10 or B50 life?

• Oil consumption costs

• Estimated v. Guaranteed M&R costs.
Thank you!

For additional information, please contact your nearest Caterpillar dealer:

http://www.cat.com/dealer-locator

Online:

E-mail:
lopez_mauricio_a [at] cat [dot] com, 954-885-3172

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