Carbon Management Workshop: Digester Economics for a Complete Mix Digester

3/27/12

AgStar 2012: Got Manure?

Bernard Sheff, PE President
UTS Residual Processing, an Anaergia Company
Economics of Total Mixed Digestion

1. Introduction
   a. Who is Anaergia
   b. The UTS Advantage

2. The Total Mixed Digester

3. What impacts the Design and Cost of a Digester:
   1. Manure Management and Bedding
   2. Ambient Conditions

4. Impact of Substrates on a Mixed Substrate Design

5. Digester Economics based on Dairy Herd Size

6. Summary
Anaergia Group of Companies

UTS Biogastechnik, GmbH
UTS Products, GmbH
UTS Residual Processing, LLC
UTS Bioenergy, LLC
Pharmer Engineering Inc.

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Anaergia / UTS in North America

- Anaergia Inc. Headquarters – Toronto, Canada
- 4 offices and 50 employees across US and Canada
- UTS Bioenergy - Encinitas, California
  - Energy project financeer/developer
  - Fuel cell and CHP PPAs
  - Biomethane upgrading for vehicle fueling and pipeline injection
- UTS Residuals – Eaton Rapids, Michigan
  - Develop biogas projects for Agricultural applications and UTS equipment
2.0 Typical Total Mixed Digester
3.0 Design Factors...

Implied Cost

- Manure Management Technique will have significant impact on the design of the digester; both conveyance, sizing, hydraulic and solid detention times and organic loading rate.
- Ambient temps and environmental conditions will impact parasitic loads and heating requirements
- Available substrates, haul distances, stability of substrates.
- When and how to mix
- Pasteurization: Class A digestion residuals
Why are Manure Management and Bedding Significant Factors?

• Manure Management
  – Scrape; Free stall is the most suitable for whole effluent, high solids digestion,
  – Flush Flume; alternative. Thickening is possible but key is to digest both solids and liquid fractions.
  – Flush; Problematic. Higher volumes; high loading or recycle important to prevent washout.
  – Dry Lot; environment critical. May be so many cows but so little USEABLE manure; Open lot Flushed, worst of both worlds
• Bedding:
  – Organic including Rice Hulls, Compost, Digested Solids (the economics of a number of Dairy Digesters has been based on Bedding);
  – Sand;
  – Other.
Some other Issued with Dry Lots and Flushing

• Dry Lots
  – Collection of manure on a dry lot is problematic:
  – Collection contamination;
  – The longer the manure is left on the lot more the volatile solids are lost;
  – One day on the feed lane yields manure that begins digestion more quickly with minimal loss of biogas potential.
Feed aprons – for daily scraping to digester
Typical Southwest and Western Dry lot Dairy
Typical Dry Lot Loading Corral Scrape
Dry Lot Manure Staging
BioMethane Potential Testing Results

8_4 UTS Pecos Gas Production

- Daily Scrape
- As-Excreted
- Weekly Scrape
- Green water
- Seed Stock

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BMP for AE, DS and WS Samples

Avg WS = 0.18 mL/mg
Avg DS = 0.28 mL/mg
Avg AE = 0.32 mL/mg
Ash, Volatile & Fixed Carbon Content of As-Excreted, Daily Scrape, and Weekly Scrape Samples (% dry weight basis)

- **Ash**: Blue bars
- **Volatiles**: Red bars
- **Fixed C**: Green bars

**Samples**
- As-Excreted
- Daily Scrape
- Weekly Scrape

**Graph Details**
- Y-axis: Percentage (%)
- X-axis: Sample Type

**Legend**: UTS

**Footer Text**: Reliable Biogas Technology.
Flush Issues

• Flushing
  – Thickening of manure using screens is a way to recover manure solids for bedding or composting and not digestion,
  – The washed fibers will generate some biogas; solids from two stage separation will generate less than 25% of the biogas that whole manure will generate
  – Why?
  – Most of the gas generating compounds are soluble, dissolved and suspended solids which are not captured on a separator or via chemical recovery.
How does flushing impact digester Economics?

Mixed Free Stall and Open Lot Dairy
System Heat Requirement/Flush Flow vs Manure % Solids Concentration

System Heat Requirement (kW)

Flow (MT/day)

Manure Solids Percentage

Nine (9) Digesters
Seven (7) Digesters
Four (4) Digesters

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4.0 Mixed Substrate Case Study

- AD Project for mixed substrate
- Substrates included dairy and swine manures, food processing residuals, municipal waste activated sludge, cafeteria waste.
  - Develop project team, contractors, tank supplier, engines, etc.
  - P&ID, Pipe schedules, motor location diagrams, wiring schedules and layout drawings.
- UTS provided contractors with specifications and drawings to refine bids and reduce contingency.
- Goal to bring Contingency to minimum by having accurate tight bidding.
- In the end, the cost was within $100,000 of first cut estimate but contingency was cut significantly.
Design Basis & System Configuration

<table>
<thead>
<tr>
<th></th>
<th>Unit</th>
<th>Manure</th>
<th>Cafeteria Waste</th>
<th>Fruit and Vegetable Waste</th>
<th>Biosolids</th>
<th>Misc.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow Phase I</td>
<td>Gpd</td>
<td>m³/d</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4,595</td>
<td>17.39</td>
<td>591</td>
<td>2,560</td>
<td>3,939</td>
<td>788</td>
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<tr>
<td>Flow Phase II</td>
<td>Gpd</td>
<td>m³/d</td>
<td></td>
<td></td>
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<td>4,595</td>
<td>17.39</td>
<td>788</td>
<td>2,560</td>
<td>13,129</td>
<td>1,641</td>
</tr>
</tbody>
</table>
### Project Summary

<table>
<thead>
<tr>
<th></th>
<th>Unit</th>
<th>Phase I Summary</th>
<th>Phase I (potential)*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Digester Volume</strong></td>
<td>M³</td>
<td>1,882</td>
<td>1,882</td>
</tr>
<tr>
<td></td>
<td>US gal</td>
<td>497,327</td>
<td>497,327</td>
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<tr>
<td><strong>Dilution Water Requirement</strong></td>
<td>M³/d</td>
<td>19.7</td>
<td>31.9</td>
</tr>
<tr>
<td></td>
<td>Us gal/d</td>
<td>5,219</td>
<td>8,421</td>
</tr>
<tr>
<td><strong>Hydraulic Retention Time</strong></td>
<td>Day</td>
<td>28</td>
<td>21</td>
</tr>
<tr>
<td>(assuming fresh water dilution)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Hydraulic Retention Time</strong></td>
<td>Day</td>
<td>33</td>
<td>25.6</td>
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<tr>
<td>(assuming 50% recycle)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td><strong>Volatile Solids Fed</strong></td>
<td>Kg/d</td>
<td>5,483.5</td>
<td>8,000</td>
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<tr>
<td></td>
<td>Lb/d</td>
<td>12,089</td>
<td>17,637</td>
</tr>
<tr>
<td><strong>Organic Loading Rate</strong></td>
<td>KgVS/m³/d</td>
<td>2.91</td>
<td>4.25</td>
</tr>
<tr>
<td></td>
<td>Lb/ft³/d</td>
<td>0.18</td>
<td>0.27</td>
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<tr>
<td><strong>Biogas Production.</strong></td>
<td>Scfm</td>
<td>68</td>
<td>138.6</td>
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<tr>
<td></td>
<td>NM³/d</td>
<td>2,759</td>
<td>5,653</td>
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<tr>
<td><strong>CH₄, as % of Biogas</strong></td>
<td>%</td>
<td>56</td>
<td>62</td>
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<tr>
<td><strong>CH₄ Production</strong></td>
<td>scfm</td>
<td>38</td>
<td>86.2</td>
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<tr>
<td></td>
<td>NM³/d</td>
<td>1,547</td>
<td>3,515</td>
</tr>
</tbody>
</table>

*Potential is calculated assuming the availability of 14 tanker loads of FOG per month.
The system is designed to handle the above organic load with the exception of CHP.
# Project Summary, cont.

<table>
<thead>
<tr>
<th>Unit</th>
<th>Phase I</th>
<th>Phase I (potential)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH₄ Production</td>
<td>scfm</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>NM³/d</td>
<td>1,547</td>
</tr>
<tr>
<td>Energy Production</td>
<td>Electrical kW</td>
<td>250</td>
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<td></td>
<td>Thermal kW</td>
<td>297</td>
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<tr>
<td>Engine Efficiency</td>
<td>%</td>
<td>86.8%</td>
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<td>Engine Availability</td>
<td>%</td>
<td>95%</td>
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<tr>
<td>Overall Efficiency</td>
<td>%</td>
<td>82.46%</td>
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<tr>
<td>Annual Electrical Output</td>
<td>Electrical kWh/yr</td>
<td>2,080,500</td>
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<tr>
<td></td>
<td>Thermal kWh/yr</td>
<td>2,464,000</td>
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<tr>
<td>Project Cost</td>
<td>USD</td>
<td>4,095,111</td>
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<tr>
<td>Capital Cost per Annual kWh Produced</td>
<td>USD/kWh/yr</td>
<td>$1.97</td>
</tr>
</tbody>
</table>

*Potential is calculated assuming the availability of 14 tanker loads of FOG per month. The system is designed to handle the above organic load with the exception of CHP.
## Bid Summary and Analysis – Public Record

<table>
<thead>
<tr>
<th>Firm</th>
<th>Base Bid Cost</th>
<th>Annual KW Power</th>
<th>O and M Cost</th>
<th>Estimated KWe</th>
<th>95% uptime</th>
<th>Cost per KWe</th>
<th>O &amp; M Cost per Kwe</th>
<th>Corrected O&amp;M Cost no labor</th>
<th>Diff in CapX Cost Versus Firm 1</th>
<th>Corrected O&amp;M for Labor vs. Firm 1</th>
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</thead>
<tbody>
<tr>
<td>Firm 1</td>
<td>$ 4,095,111.00</td>
<td>2080500</td>
<td>$ 107,599.00</td>
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<td>$ 16,380</td>
<td>$ 0.052</td>
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<td>Firm 2</td>
<td>$ 4,700,000.00</td>
<td>986800</td>
<td>$ 119,000.00</td>
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<td>$ 39,637</td>
<td>$ 0.121</td>
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<td>Firm 3</td>
<td>$ 4,791,087.00</td>
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<td>$ 34,660.00</td>
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<td>$ 20,921</td>
<td>$ 0.018</td>
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<td>$ 695,976.00</td>
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<td>Firm 4</td>
<td>$ 4,203,889.00</td>
<td>2483460</td>
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<td>$ 14,087</td>
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<td>$ 108,778.00</td>
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<td>Firm 5</td>
<td>$ 5,250,000.00</td>
<td>3593000</td>
<td>$ 61,250.00</td>
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<td>$ 1,154,889.00</td>
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<td>Firm 6</td>
<td>$ 11,300,000.00</td>
<td>2049840</td>
<td>$ 40,000.00</td>
<td>246</td>
<td>$ 45,876</td>
<td>$ 0.020</td>
<td>$</td>
<td>$ 7,204,889.00</td>
<td>$ 7,401.00</td>
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<td>Firm 7</td>
<td>$ 4,700,000.00</td>
<td>2000000</td>
<td>$ 45,000.00</td>
<td>240</td>
<td>$ 19,557</td>
<td>$ 0.023</td>
<td>$</td>
<td>$ 604,889.00</td>
<td>$ 12,401.00</td>
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<td>Firm 8</td>
<td>$ 4,649,829.00</td>
<td>1975000</td>
<td>$ 36,800.00</td>
<td>237</td>
<td>$ 19,593</td>
<td>$ 0.019</td>
<td>$</td>
<td>$ 554,718.00</td>
<td>$ 4,201.00</td>
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</tbody>
</table>
5.0 Economics of Anaerobic Digestion based on Dairy Herd Size

Dairy Application, Scrape w/ organic bedding, Elec. Power Generation, includes O & M on engine and system
Breakeven cost per kWe manure only
Breakeven cost per kWe with Substrates added (10% of manure vol.)
6.0 Summary: Economics of Digesters

- Best case is for a 3500 to 4000 head, fiber bedded, scrape management dairy: 1 MWe could be realized from digestion of manure only.
- Flush systems become very problematic both in size and heating requirements;
- In general a scrape/organic bedded site will use 25% of total heat generated by engines;
- Dry lots provide only 40% of the actual manure generated due open lot recovery issues;
- Arid lands can have significant impact on manure quality;
- Digestion at sand bedded is feasible but also challenging; easiest with mechanical separation and require recycle.
6.0 Summary, continued

- The 1 MWe scrape facility would need a payback on electric energy only in the range of $0.11 per kW-hr to simply break even. This is based on Cap-X costs, total of $0.03 total maintenance on engine and system, 10 year financing.

- Substrates can greatly impact this model, but have the potential to affect many other issues; material handling, nutrient management, permitting, off-take agreement.

- Significant issue is how long is contract for substrate supply? Numerous digesters have been partially completed only to not fund due to length of contract on the substrates.

- As expected as the number animal units increases the Cap-X per KWe drops but manure management becomes more of concern. More animals means more advanced handling and probably more WATER.
6.1 Questions to Ask: Time = Money

- Questions to ask:
  - Do you have funding in place?
  - Number of cows, chickens, feeders, etc.? Manure management system? Bedding? Substrates to be utilized?
  - Dairy: Solids Content of Manure, interest in conversion of bedding?
  - Do you have an off take agreement, i.e., is there an entity in place to purchase what you are selling (high BTU bio-methane or electricity)?
  - Is project viability based on sale of bi-products? Be very wary of projects where selling processed substrates is a large portion of the income stream.
  - Do you have funding in place?
Thanks to:

- Pecos Valley Biomass Cooperative
- New Mexico Dairy Producers Association
- Senator Jeff Bingaman
- US Department of Energy
- Fair Oaks Dairy
- Michigan State University
In the end there must be a reason, just beyond money, to do this. It is a simple fact that we must have clean water and energy to subsist.

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