Overview of Farm Anaerobic Digesters Opportunities in Manure Management and Renewable Energy

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Focus on Energy Program

Flows in an Anaerobic Digester System

Digester Heating Circuit – Engine or Boiler Sources

Complete Mix Anaerobic Digester

- Primarily used for manure in a range of 3 - 10% solids
- Digester can be above or below ground tanks
- Flexible inner and outer covers:
  -- inner cover expands with biogas
- General Characteristics:
  - Temperature control with complete mixing (paddles or props)
  - Typical retention times (15 - 30 days)
  - Can be operated at mesophilic or thermophilic temperatures
  - Capital cost can be somewhat higher than plug-flow systems

Vir-Clar Farm
Fond du Lac
mesophilic
complete mix, 340 kW
Biogas Nord GmbH / Energies Direct

Crave Brothers Farm
Waterloo, WI
mesophilic
complete mix, 250 kW
American Biogas Co.
**Plug-Flow Anaerobic Digester**

- Primarily used for high solids manure (> 8%)
  - Material moves through digester as a plug
- Rigid covers for gas collection (e.g., concrete)
- General Characteristics:
  - Temperature control with limited mixing
  - Typical retention times (20 - 30 days)
  - Typically operated at mesophilic temperatures
  - Solids deposition may be a problem for sand/grit or if the solids content changes substantially (summer use of sprinklers)
- Mixed plug-flow systems are available
Holsum Dairy
Elm Rd., Hilbert, WI
mesophilic
modified plug-flow; 1,200 kW
GHD, Inc.

Clover Hill Dairy
Campbellsport, WI
mesophilic
modified plug-flow, 300 kW
GHD, Inc.

Emerald Dairy
Emerald, WI
mesophilic
diffusion
modified plug-flow
pipeline CH4
GHD, Inc.

Wisconsin’s Anaerobic Digester Projects
- 23 - Operating Farm Digesters
- 7 - Farm Digesters Under Construction
- 4 - New Industrial or Municipal Digesters Under Construction

March 1, 2009

Uses for Biogas
- H2O
dehumidification
- CH4
- chiller
- water heating
- CO2
carbon dioxide scrubber
- methane
- generator
- absorption chilling
- H2S
- scavenger iron sponge
- liquid water condensate return
- space heating

Biogas Boiler Considerations
GOAL: Obtain a blue, compact and stable flame indicating complete combustion.
Biogas needs less air than most other fuels and requires a specific burner and/or air control design. This design usually involves:
- 2 to 4 times expanded injector cross section to increase gas flow for maintaining pressure drop and exit velocity
- modified controls for reducing combustion air supply
- operate at sufficient temperature (> 280° F) to prevent condensation of water leading
- avoid copper and steel components
- dual fuel burners for propane/LP or biogas
- reduce hydrogen sulfide content of biogas
- use stainless steel pipes
- reduce moisture content of biogas
Engine-Generators Considerations

- High first costs
- A backup biogas boiler may be a good idea
- Maintenance costs
- Operational issues e.g., nuisance tripping off-line
- Operation at low loading (60% or less) is inefficient
- Electric buyback rates
- Smaller generators can be less efficient
- Limited smaller sized equipment
- Engine-generators should be designed for biogas
- Three-phase line extensions are expensive

Liquid-Solid Separator

Value-Added Products from Biosolids

Phosphorus in Wisconsin Soils

Separators can recover up to about 30% phosphorus without flocculants

% removed depends on separation system used and settings

Digester System

Digested Liquids

Phosphorus

Soil Test P

SOIL TEST P
1995-1999

Reduced N,P&K

Additional Reduced N,P&K

Reduced N,P&K

Bustles Utilized per Nutrient Management Plan

Digested Solids for Off-Farm Uses

Digested Solids

Digester System

Digestor CHP Gas Cleanup and Separator

Digested Liquids

Irrigated

Reduced N,P&K

Digested Liquids Pond 1

Digested Liquids Pond 2

Digested Solids

For Animal Bedding

Digested Solids

Phosphorus in Wisconsin Soils

Separators can recover up to about 30% phosphorus without flocculants

% removed depends on separation system used and settings
The nutrients nitrogen, phosphorus and potassium are available in fresh animal manure. Much of the total nutrient content of manure is not immediately available for plants because they are in the organic form. Roots require inorganic (mineralized) forms of nutrients to pass their cell membranes for plant uptake. Organic nutrient break-down may take several years during which about half of the nitrogen may be lost as gas to the atmosphere. Up to 50% of the nitrogen, phosphorus and potassium may be lost to leaching and runoff. Nutrients will be in more readily available if the manure is digested before being applied to the soil.

Develop and implement an annual field-specific nutrient application plan.

The timing of nutrient applications for various crops is critical. For example, corn takes up nitrogen rapidly beginning about 6 weeks after planting and continuing until 10 to 12 weeks after planting.

Practice precision nutrient application when possible.

Apply digester nutrients when the plants can utilize them and there is no forecasted rain for several days.

### Slurry Analysis From Ponds – per 1,000 gallon

<table>
<thead>
<tr>
<th></th>
<th>First Pond</th>
<th>Second Pond</th>
<th>Ave. Raw Manure</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Dry Matter</td>
<td>3.7</td>
<td>2.1</td>
<td>11</td>
</tr>
<tr>
<td>N, lb.</td>
<td>9.9</td>
<td>6.3</td>
<td>7</td>
</tr>
<tr>
<td>P₂O₅, lb.</td>
<td>3.7</td>
<td>2.2</td>
<td>7</td>
</tr>
<tr>
<td>K₂O, lb.</td>
<td>10.4</td>
<td>9.8</td>
<td>18</td>
</tr>
</tbody>
</table>

### Nutrients amounts removed from the soil by corn (stover and grain at a yield level of 150 bushels/acre)

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Grain, lb/acre</th>
<th>Stover, lb/acre</th>
<th>Total, lb/acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen (N)</td>
<td>120</td>
<td>51</td>
<td>171</td>
</tr>
<tr>
<td>Phosphorus (P)</td>
<td>24.8</td>
<td>6.1</td>
<td>30.9</td>
</tr>
<tr>
<td>Phosphorus (P₂O₅)</td>
<td>57</td>
<td>14</td>
<td>71</td>
</tr>
<tr>
<td>Potassium (K)</td>
<td>30.8</td>
<td>125</td>
<td>155.9</td>
</tr>
<tr>
<td>Potassium (K₂O)</td>
<td>37</td>
<td>150</td>
<td>187</td>
</tr>
</tbody>
</table>

Source: UW-Extension 2004
Advanced Nutrient Removal Methods
--- liquid digestate fractionation ---

**Anaerobic Digester**

<table>
<thead>
<tr>
<th>Influent</th>
<th>Effluent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mostly organic N = N</td>
<td>P = P</td>
</tr>
<tr>
<td>More inorganic K = K</td>
<td></td>
</tr>
</tbody>
</table>

**Screening and Ultrafiltration**

- **Screening:**
  - P: up to -30%
  - N: -13%
  - NH₄⁺ strip
  - P and K concentrate

**Reverse Osmosis**

- **Water:** P and K concentrate
- **P and K:** up to -30%

<table>
<thead>
<tr>
<th>Size, micrometers (µm)</th>
<th>≤ 0.001 µm</th>
<th>0.001 to 0.1 µm</th>
<th>0.1 to 1 µm</th>
<th>1 to 10 µm</th>
<th>10 to 100 µm</th>
<th>100 to 1000 µm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Materials</td>
<td>salt and metal ions</td>
<td>viruses</td>
<td>bacteria</td>
<td>colloidal particles</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Separation Type</td>
<td>reverse osmosis</td>
<td>ultrafiltration</td>
<td>microfiltration</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Benefits of an Anaerobic Digester System – Part 2**

- Reduced odors
- Provides high-quality fertilizer = high quality nitrogen availability for plants
- Quality animal bedding and high-P digested solids for sale
- Reduced surface and groundwater contamination
- Reduced pathogens and weed seeds
- Reduced emissions of methane from manure decomposition
- Produces renewable energy and lessens fossil fuel use
- Job creation - design, operation, and manufacture of systems

**Green Valley Dairy**

Shawano Co., WI  2,500 dairy cows

The manure flow rate to the digester approximately 80,000 gallons per day.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Average Influent</th>
<th>Average Effluent</th>
<th>Units</th>
<th>Destruction or Change</th>
<th>Pounds Removed per Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total solids</td>
<td>7.3</td>
<td>5.1</td>
<td>%</td>
<td>38.14%</td>
<td>15,578</td>
</tr>
<tr>
<td>Total volatile solids</td>
<td>65.4</td>
<td>75.5</td>
<td>%</td>
<td>34.86%</td>
<td>15,184</td>
</tr>
<tr>
<td>Chemical oxygen demand</td>
<td>52,710</td>
<td>32,295</td>
<td>mg/L</td>
<td>40.73%</td>
<td>13,621</td>
</tr>
<tr>
<td>Soluble chemical oxygen demand</td>
<td>16,247</td>
<td>7,833</td>
<td>mg/L</td>
<td>51.79%</td>
<td>5,251</td>
</tr>
<tr>
<td>Total volatile acids</td>
<td>3,370</td>
<td>300</td>
<td>mg/L</td>
<td>85.16%</td>
<td>1,915</td>
</tr>
<tr>
<td>Total Kjeldahl nitrogen</td>
<td>2,708</td>
<td>2,953</td>
<td>mg/L</td>
<td>7.47%</td>
<td>173</td>
</tr>
<tr>
<td>Ammonia nitrogen</td>
<td>1,132</td>
<td>1,297</td>
<td>mg/L</td>
<td>-15.73%</td>
<td>-110</td>
</tr>
<tr>
<td>Total phosphorus</td>
<td>379</td>
<td>319</td>
<td>mg/L</td>
<td>18.21%</td>
<td>47</td>
</tr>
<tr>
<td>Soluble phosphorus</td>
<td>202</td>
<td>184</td>
<td>mg/L</td>
<td>17.12%</td>
<td>23</td>
</tr>
<tr>
<td>Fecal coliform</td>
<td>2,858,771</td>
<td>29,798</td>
<td>CFU/g</td>
<td>90.00%</td>
<td>-</td>
</tr>
<tr>
<td>Fecal streptococcus</td>
<td>2,311,146</td>
<td>141,131</td>
<td>CFU/g</td>
<td>92.63%</td>
<td>-</td>
</tr>
<tr>
<td>pH</td>
<td>7.7</td>
<td>7.7</td>
<td></td>
<td>0.00%</td>
<td>-</td>
</tr>
</tbody>
</table>

**Performance Assessment of Farm Digester Energy Systems**

- Green Valley Farm, Shawano County, WI
- UW-Green Bay performed sampling and analysis
- Badger Laboratories performed laboratory sample analysis
- Chemical, biological & energy parameter measurements of influent and effluent taken every two weeks for one year: August 2007 – July 2008
- gas flow and electricity produced
- quantity of influent
- nutrients N, P and K
- solids
- volatile solids
- COD
- fecal coliform and fecal streptococcus
- pH

The methane content was found to be at 53.6%, and the carbon dioxide content was 43.8%.

There were 7,656 hours during the duration of the sampling period. The capacity factor of the engine was 73%; that would yield approx. 3,553,000 kWh
### Parameter With Anaerobic Digestion

<table>
<thead>
<tr>
<th>Parameter</th>
<th>With Anaerobic Digestion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Odor</td>
<td>Substantial reduction</td>
</tr>
</tbody>
</table>
| Greenhouse Gas Emissions   | • Methane - substantial reduction (2.32 tons per cow-yr on a carbon dioxide equivalent basis)  
• Carbon dioxide - 1.33 tons per cow-yr associated with the reduction in fossil fuel use to generate electricity |
| Ammonia Emissions          | No significant reduction |
| Potential Water Quality Impacts | • Oxygen demand - substantial reduction (5.1 lb per cow-day)  
• Pathogens - substantial reduction  
• Fecal streptococcus: >99%  
• Nutrient enrichment - no reduction |
**Focus on Energy**

**Target Markets for Customer-Owned Renewable Energy**

- **Solar**
  - Electrical Generation
  - Water Heating
- **Wind**
- **Bioenergy**
  - Non-residential Biomass Combustion
  - Anaerobic Digestion

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**Tools for Priming the Bio-energy Market**

- **Information**
  - GIS Renewable Resource Assessment
  - Agriculture Biogas Casebook
  - Municipal Wastewater to Methane Assessment
- **Project facilitation – Connections**
  - Marketing
    - Case studies and conferences
    - Supply & demand lists
  - Technical assistance
  - Industrial & agricultural solicitation
- **Financial incentives**

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**Available Funding for Digesters – part 1**

**Focus on Energy Feasibility Study Grants**

- for technical and economic feasibility analysis
- maximum $10,000 award
- minimum 50% cost match
- may be applied for in a multi-phase approach

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**Available Funding for Digesters – part 2**

**Focus on Energy Dairy Farm Anaerobic Digester Grant**

- award levels based on kWh or therm production per year
- maximum award up to 25% of project cost or $250,000
- for projects that cost $2 million or less
- thermal projects must be connected to natural gas service of participating natural gas provider
- feasibility study required prior to application

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**Available Funding for Digesters – part 3**

**Focus on Energy Opportunity Grant**

- award levels based on kWh or therm production per year
  
  \[
  \text{Grant Award} = 0.08 \times (\text{annual electricity kWh} – \text{annual parasitic energy kWh}) + 0.35 \times (\text{annual therms utilized})
  \]

- maximum award up to 25% of project cost or $500,000
- for projects that cost between $2 million and $5 million
- thermal projects must be connected to natural gas service of participating natural gas provider
- feasibility study required prior to application

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**Available Funding for Digesters – part 4**

**USDA Rural Energy for America Program (REAP)**

- (formerly Section 9006 Program)
  - maximum award up to 25% of project cost or $500,000
  - applicant must be a rural small business and located in a rural area

**DATCP Agricultural Development and Diversification Grant (ADD)**

- for new value added products, new production techniques and alternative enterprises
- maximum grant $50,000
American Recovery and Reinvestment Act of 2009
Subtitle E - Energy Incentives — Preliminary Information —

Section 48 - Investment Tax Credit
• 30% Investment Tax Credit in lieu of a Section 45 Production Tax Credit

Section 1603 - Grants in Lieu of Tax Credits
• 30% of energy property cost may be converted to a grant
• for energy property placed in service during 2009 or 2010, or construction began during 2009 or 2010
• not includible as gross income
• basis of property shall be adjusted by grant value
• federal, state or local governments are not eligible

Bonus Depreciation
• 50-percent bonus depreciation

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