Farm Energy IQ

Farms Today Securing Our Energy Future

On-Farm Biogas Production and Use

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What You’ll Learn

- How organic feedstock is converted to useful energy
- The technologies and how they work
- What operating systems look like
- How much organic material is needed per unit of energy
- Best practices for using biologically-derived methane
- How to calculate useful energy production
- Safety concerns

What’s the Technology?

Anaerobic digestion
- Organic matter in air tight, oxygen-free enclosure
- Without oxygen, organisms digest organic matter and produce methane
- In a biodigester
- Organic matter in slurry—such as liquid manure and finely chopped vegetable matter—is injected
- Small particles are more accessible to the bacterial microbes to consume

Converting Organic Matter to Methane

Organic matter includes low-value biodegradable material that would otherwise require sustainable disposal

Typical feedstock includes:
1. Liquid livestock manure
2. Manufacturing waste products like whey, potato peels, fruit skins, husks, hulls and vegetable food scraps.

How does a digester function?

Graphic credit: Afrisol Energy LTD. (Afrisolenergy.com)
I suggest trying to find a more relevant graphic that reflects U.S. nomenclature (e.g., "manure instead of dung" and our typical use of biogas (electrical generation, not cooking and lighting)

Jeannie Sikora, 12/6/2014

I suggest using "liquid" to convey no straw, etc.

Jeannie Sikora, 12/6/2014
Keeping a digester “healthy”

- An oxygen free environment
- Fresh liquefied feedstock injected twice a day with minimal, if any, solids and no non-organic contaminants
- Maintain temperature between 95°F to 100°F (35°C to 38°C)
- A pH balanced between 6.6 and 7.6

The right balance of bacteria

Acid-forming bacteria can survive:
- Inhibits anaerobic fermentation
- Hypoxic or anaerobic conditions
- Viable or active bacteria
- A band of organics composed of a food source

Methane-forming bacteria can survive only:
- If temperature is held slightly constant
- In a narrow band of pH conditions
- Active bacteria
- No single organic acids as a food source

Biogas Composition

- CH₄ - methane - 550 to 700 Btu/ft³ (2.05 x 10⁷ to 2.61 x 10⁷ Joule/m³)
- CO₂ - carbon dioxide
- H₂S - hydrogen sulfide

Three Step Process

1. Liquefication: Liquefied feedstock
2. Acid Production: Hydrolysis and Solubilization to simplify undegraded materials
3. Methane Production: Biogas (CH₄) formation

Sizing Considerations

- Manure from a typical 1,400 lb. cow produces about 4 kWh/day of electricity
- 4 kWh/day x 365 days/year = 1,460 kWh/yr
- 1,460 kWh is worth about $146
- Generator sizing
  - Divide 1,460 kWh/cow/yr by 8760 hours/yr to determine electric power output (~0.17 kW/cow/yr)
  - Generator will also produce waste heat to temper feedwater or for cleaning
This cracked me up. I created this graphic in 1994 for a fact sheet, while working for Bob Graves in my very first job out of grad school.

Jeannie Sikora, 12/6/2014
Sizing Considerations
• Supplying enough methane gas to power a 20 kW generator, given 0.17 kW per cow production rate, requires approximately 120 cows
• Cow manure is not the richest manure in terms of power output because cows efficiently digest much of the energy contained in their feed

Sizing considerations
• Biogas produced from dairy manure is typically about 60% methane
• As a result, the methane proportion of the dairy cow biogas may not be sufficient to operate a generator at full load

Sizing considerations
• To boost methane content, one dairyman we know adds whey from a nearby cheese operation and distiller’s wet grain solubles (DWGS) to the dairy manure
• These enrichments increase the methane content in the biogas to enable operating a generator at full load throughout the year

That 20 kW electric generator...
• Will produce 150,000 kWh/Yr. (+ or -)*
• Will offset about $15,000 per year in electric costs
• Will produce waste heat to maintain digester operating temperature during cold weather
• Remaining excess heat goes to a radiator or can be used to preheat cleaning water

Comparing Energy in Other Waste

<table>
<thead>
<tr>
<th>Feedstock</th>
<th>Number of animals to produce 1 ton</th>
<th>Dry Matter Content</th>
<th>Biogas Yield (dry)</th>
<th>Energy Value (kWh/t) Biogas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cattle Steer</td>
<td>20-40</td>
<td>12</td>
<td>25</td>
<td>25-25</td>
</tr>
<tr>
<td>Pig Steer</td>
<td>256-300</td>
<td>9</td>
<td>20</td>
<td>21-25</td>
</tr>
<tr>
<td>Laying Hens Litter</td>
<td>5,000-6,000</td>
<td>18</td>
<td>50-100</td>
<td>20-22</td>
</tr>
<tr>
<td>Broiler Mixture</td>
<td>16,000-15,000</td>
<td>60</td>
<td>60</td>
<td>21-23</td>
</tr>
<tr>
<td>Food Waste</td>
<td>-</td>
<td>15</td>
<td>40</td>
<td>21-25</td>
</tr>
</tbody>
</table>

*Assumes an 85% reliability factor, electricity priced at $0.10/kWh
Linear Plug Flow Biodigester

Source: http://www.climatetechwiki.org/technology/jiqweb-anbt

Round plug flow biodigester

Brookside Dairy Biodigester

Source: http://enermac.com/Strabab-SEHL.htm

Fixed Dome Biodigester

Source: http://www.appropedia.org/Fixed_dome_digester

Internal Combustion Engines

Modified diesel generator with thermal recovery for process heat

Photo credit: Andrew Wood, PSU Extension

Micro Turbines

A bank of 65 kW micro turbines


Methane Safety Concerns

The production of methane gas presents asphyxiation, fire, and explosion hazards:
1. Never enter a closed area where methane may be present without an appropriate breathing apparatus
2. Keep open flames and sparks away from methane production and storage areas
3. Follow code for any given application
4. Treat methane gas with the same safety precautions as natural gas—they are one and the same
5. Adhere to National Electric Code standards for wiring requirements in settings containing natural gas
Photo source? Location of digester? If unknown, suggest removing "Brookside Dairy" since it leaves us guessing.

Jeannie Sikora, 12/6/2014
**Electrical Safety Concerns**

1. Consult your local electrical provider for regulations concerning grid interconnection and operation of customer-owned electrical generation facilities.
2. Contract the services of a qualified electrical contractor to design and install electrical equipment.
3. Never operate equipment outside of its design parameters.
4. Employ a routine maintenance schedule to keep equipment in top condition.
5. Have any changes, additions, or deletions inspected by a qualified electrical inspector.

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Questions?