Farm Energy IQ

Farms Today Securing Our Energy Future

On-Farm Biogas Production and Use
Ed Johnstonbaugh, Penn State Extension

Farm Energy IQ

On-Farm Biogas Production and Use

Ed Johnsonbaugh, Penn State Extension

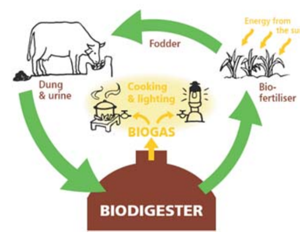
What You'll Learn

- 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 airtight, 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



Graphic credit: Afrisol Energy LTD. (Afrisolenergy.com)

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?

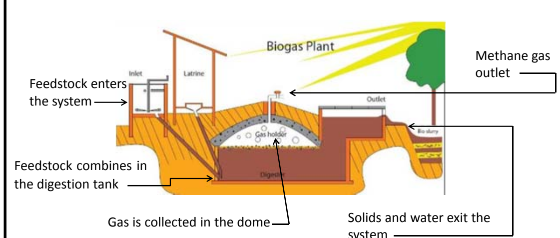


Illustration credit: En.wikipedia.org

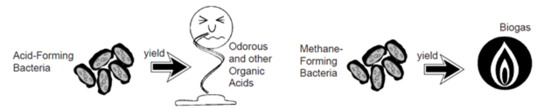
Slide 4

JS2 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

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:
- with temperature fluctuations
- in a wide range of pH conditions
- with or without oxygen
- on a broad range of organic compounds as a food source

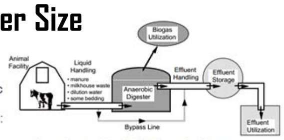
Methane-forming bacteria can survive only:
- if temperature is held relatively constant
- in a narrow band of pH conditions
- without oxygen
- on simple organic acids as a food source

Image credit: Anaerobic Digestion: Biogas Production and Odor Reduction from Manure. Penn State Cooperative Extension Fact sheet G77.

Biogas Composition

- CH_4 - methane - 550 to 700 Btu/ft^3 (2.05 x 10^7 to 2.61 x 10^7 Joule/m^3)
- CO_2 - carbon dioxide
- H_2S - hydrogen sulfide

Digester Size



To get an idea of the size of an anaerobic digester, consider one designed for 200 milking cows with a 20 day retention time:

Assuming each high-producing milking cow produces 2.2 ft^3 manure per day, the daily volume of manure from these milking cows would be:

200 cows x 2.2 ft^3 manure/day/cow = 440 ft^3 manure/day

If dilution water is needed for manure flowability or added from the milking center at a rate of 3 gallons per cow per day, the additional volume added daily would be:

200 cows x 3 gallons water/cow/day ÷ 7.5 gallons water/ft^3 water = 80 ft^3 water/day

The total material added daily to the digester, therefore, would equal:

440 ft^3 manure/day + 80 ft^3 water/day = 520 ft^3 material/day

To hold 20 days worth of manure and water, the digester volume would need to be:

520 ft^3/day x 20 days = 10, 400 ft^3

A digester with a rigid cover, a 3 ft head space for gas collection, and a material volume (no bedding included) of 10,400 ft^3, would be approximately 15 ft deep and 33 ft in diameter.

Image credit: Anaerobic Digestion: Biogas Production and Odor Reduction from Manure. Penn State Cooperative Extension Fact sheet G77.

Sizing Considerations

- Manure from a typical 1,400 lb. cow produces about 4 kWh/day of electricity
- 4 kWh/day ≈ 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 feed-water or for cleaning

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

*Assumes an 85% reliability factor, electricity priced at $0.10/kWh

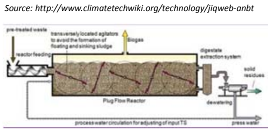
Comparing energy in other waste

Feedstock	Number of animals to produce 1 tonne/day	Dry Matter Content	Biogas Yield(M3/t)	Energy Value(MJ/m3) Biogas
Cattle Slurry	20-40	12	25	23-25
Pig Slurry	250-300	9	26	21-25
Laying Hen Litter	8,000-9,000	30	90-150	23-27
Broiler Manure	10,000-15,000	60	50-100	21-23
Food Waste	~	15	46	21-25

Source: http://www.anaerobic-digestion.com

Linear Plug Flow Biodigester

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



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

Round Plug Flow Biodigester

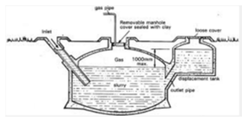
Brookside Dairy Biodigester

Slide 18

JS4 Photo source? Location of digester?If unknown, suggest removing "Brookside Dairy" since it leaves us guessing.

Jeannie Sikora, 12/6/2014

Fixed Dome Biodigester



Source: http://biogas-technology.blogspot.com/2013_06_01_archive.html Source: http://www.appropedia.org/Fixed_dome_digester

Internal Combustion Engines

Modified diesel generator with thermal recovery for process heat

Photo credit: Ed Johnstonbaugh, PSU Extension

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

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

Farm Energy IQ

On-Farm Biogas Production and Use

Questions?