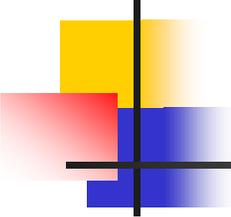


# Anaerobic Digestion Overview

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University of Minnesota  
Department of Biosystems and  
Agricultural Engineering



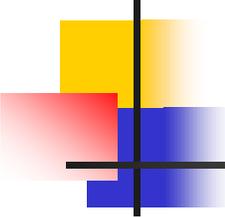
# What is Anaerobic Digestion?

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Conversion of Organic Matter  
by Anaerobic Microbes  
to Biogas and Manure Effluent



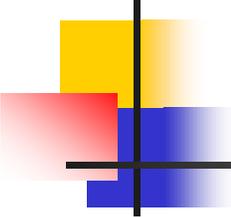
Methane ~ 60%  
Carbon Dioxide ~ 40%  
Hydrogen sulfide ~ trace



# Benefits of Digestion

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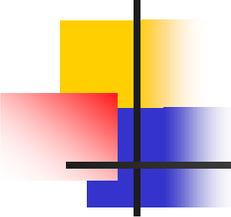
- **Odor Control**
- Energy production
- Conversion of organic N to inorganic N
- Homogeneous effluent
- Other crop benefits?
- Pathogen reduction?
- Weed seed sterilization?



# Other Key Facts

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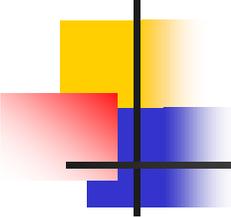
- There is "no" reduction in manure volume
- There is no reduction in manure nutrients
  - Some organic nitrogen is converted to ammonia nitrogen and could be volatilized in the manure storage
- There is no increase in manure nutrients



# History of Digestion

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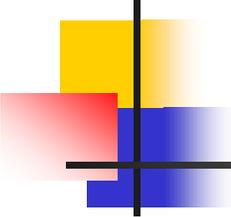
- First plant built in India in 1859
- Fueled street lamps in England in 1985
- In 1998 an estimated 600 farm-based digesters were in use.
- Estimated 31 digesters are currently in operation on farms in US



# Terms to Know

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- **Volatile Solids (VS)** - A measure of the weight of solids that is combustable "volatilized" at a temperature of 600 °C. It is reported as a percent of the total weight of the manure sample.  
Methane production is often based on the volatile solids portion of the manure.



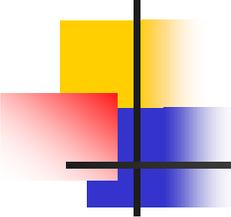
# Volatile Solids Production

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- Dairy = 10 lbs VS per day
- Swine = 8.5 lbs VS per day
- Layer = 12 lbs VS per day

(per 1000 lbs live weight)

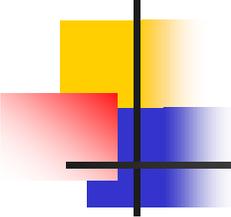
*Approximately 50-70% of the VS can be converted.  
This depends on species and digester design.*



# Terms to Know

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- **Total Solids (TS)** - The weight of the dry matter of a sample of manure and reported as a percent of the total weight of the manure sample.  
The type of digester used is based primarily on total solids content of the waste.

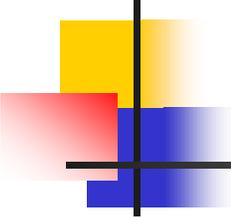


# Terms to Know

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- **Hydraulic Retention Time (HRT)** - The amount of time the manure spends in the digester. Reported as the ratio of digester volume to the amount of manure added per day.  
HRT affects the amount of methane produced.

***10 gallons per day to a 100 gallon tank has a 10 day HRT.***

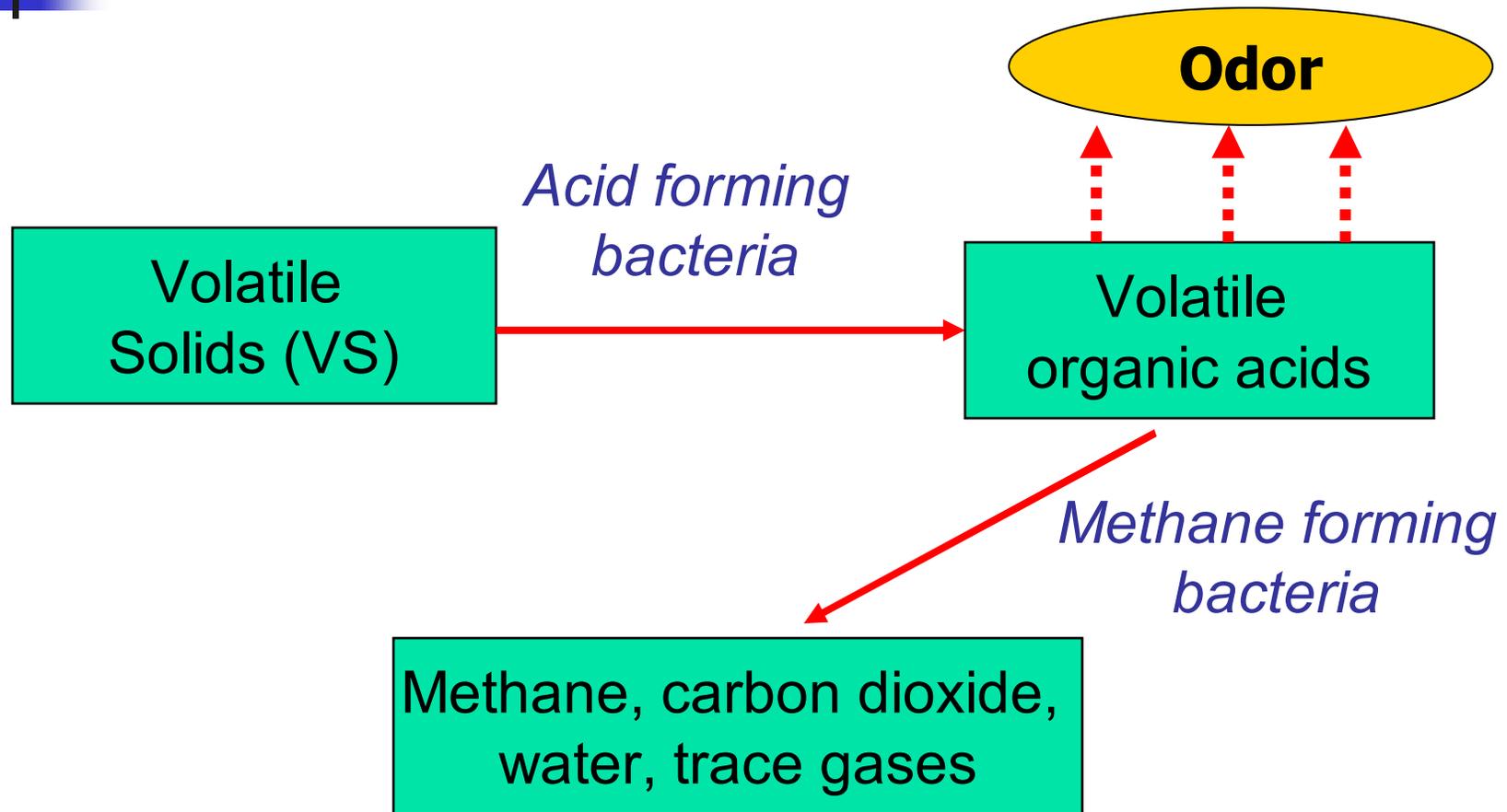


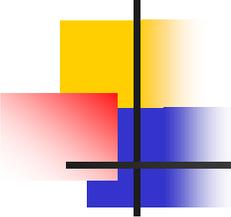
# Terms to Know

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- **Loading Rate** - amount of volatile solids per unit of time per volume of digester. A "standard" digester will have loading rates of between 0.1 to 0.5 lbs VS/day/ft<sup>3</sup> digester (30 day HRT).

# More Details on the Digestion Process

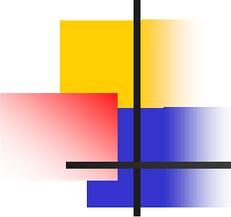




# Temperature considerations

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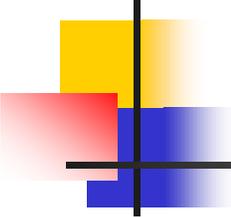
- Psychrophilic <68 °F
- Mesophilic 95-105 °F
- Thermophilic 125-135 °F



# pH considerations

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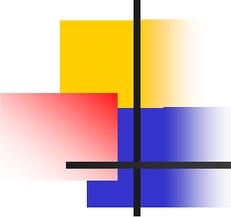
- Methane forming bacteria require pH of between 6.8 and 7.4



# Biogas composition

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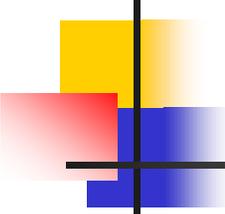
- Methane ~ 60%
- Carbon Dioxide ~ 40%
- Hydrogen sulfide ~ trace



# Methane is a Fuel Source

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- Natural gas is 99% methane
- Methane is about 900 BTU/ft<sup>3</sup>
- Propane is 2284 BTU/ft<sup>3</sup>

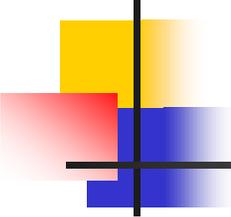


# Typical Energy Production

<b>Species</b>	per 1000 lbs live weight		
	<b>VS lb/day</b>	<b>Biogas ft<sup>3</sup>/day*</b>	<b>Energy BTU/day</b>
Dairy	10.0	39	23,400
Swine	8.5	28	16,800
Layer	12.0	37	22,000

Taken from MWPS-18

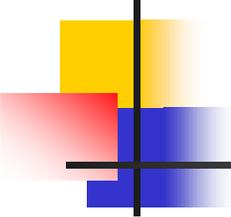
\*Biogas production is typically much higher than these reported values (often more than twice).



## Other notes

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- 20-40% efficiency in converting BTU's of methane to electricity with engine generator set.

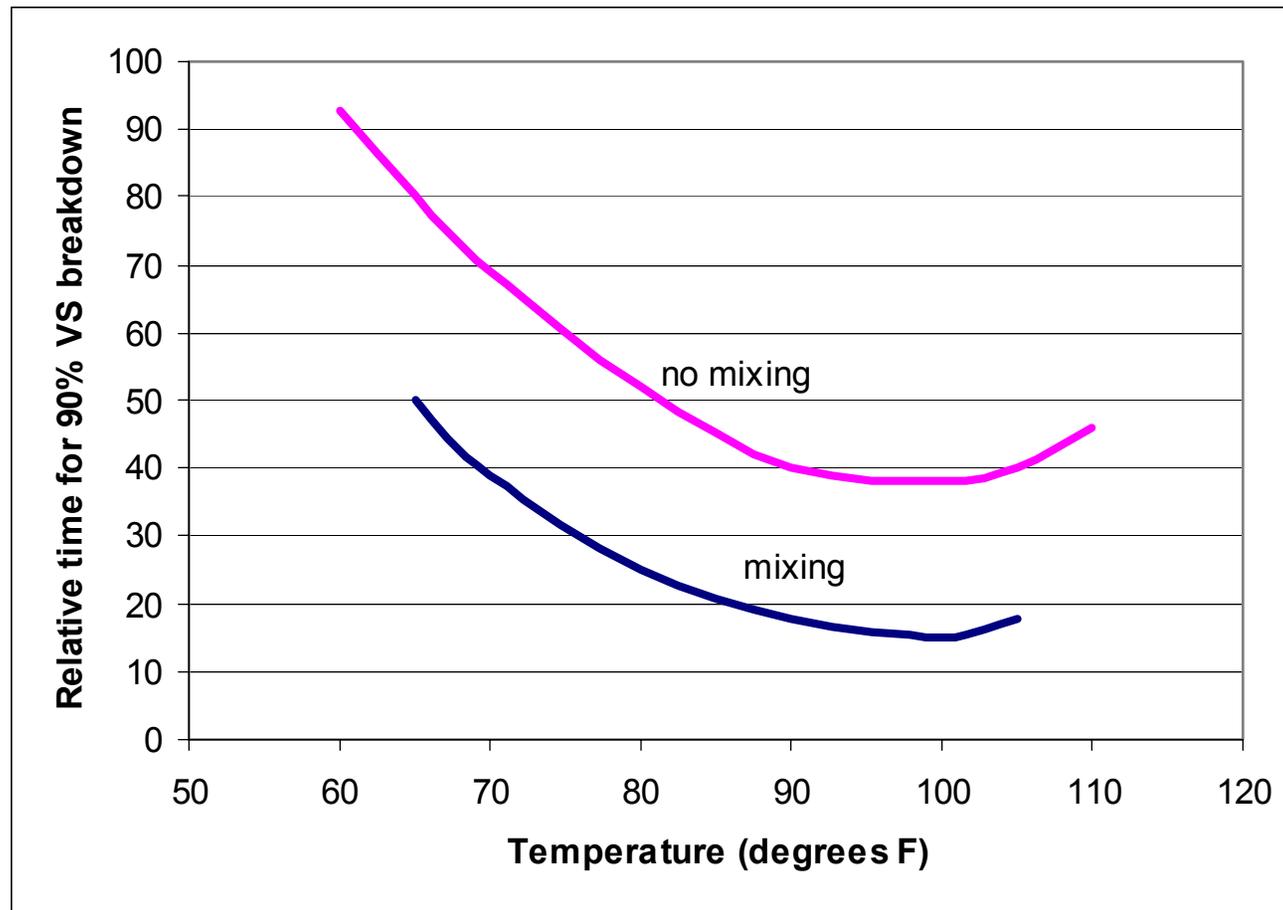


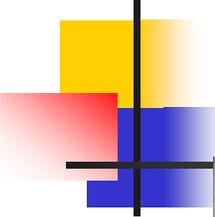
# Maximizing Methane Production

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- Control Temperature
- Control pH
- Mixing

# Mixing and Temperature effect on Digestion

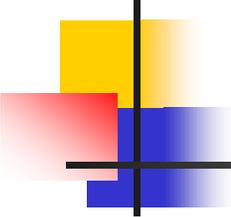




# Covered Lagoon

- Flexible cover on lagoon or manure storage
- Lowest gas production
- Least "controlled" system
- Longest HRT





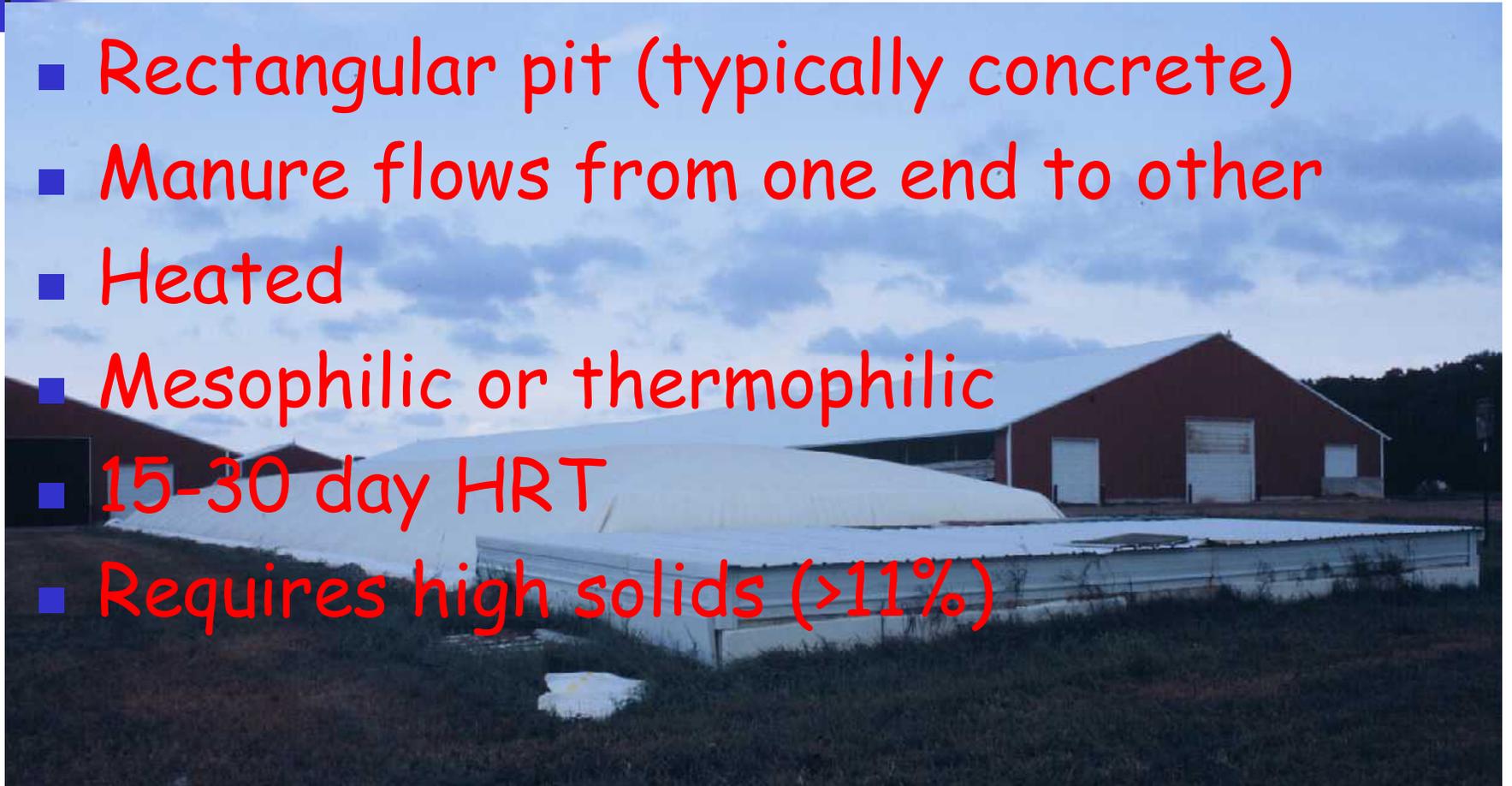
# Complete Mixed

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- Covered Tank with Mixing
- Heated
- Mesophilic or thermophilic range
- 15-20 day HRT
- 2-10% solids input

# Plugged Flow

- Rectangular pit (typically concrete)
- Manure flows from one end to other
- Heated
- Mesophilic or thermophilic
- 15-30 day HRT
- Requires high solids (>11%)

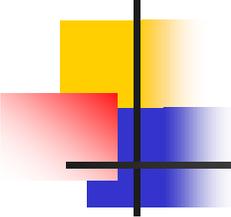


# Options for Biogas

- Flare



ing



# Options for Biogas

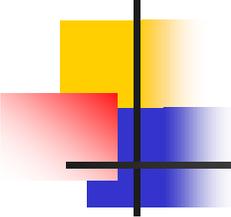
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- Boiler for Heat
  - Hot water, floor heat, room heat

# Options for Biogas

- Electricity Generation
  - Engine, micro-turbine, fuel cell

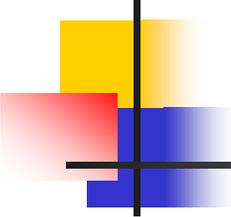




# Haubenschild Digester

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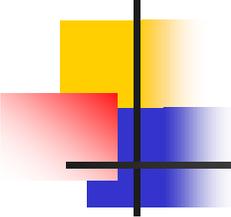
- Biogas production 93ft<sup>3</sup>/cow/day
  - (66 ft<sup>3</sup>/day/1000lb lw)
- Electrical production 4 kWh/cow/day



# Management

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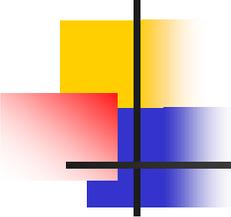
- 30 minutes per day
  - “feeding” digester
  - checking temperatures
  - monitor biogas production
  - change oil (every 700-1000 hours)



# What about solid separation?

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- Solids separate better after digestion
- Phosphorus is concentrated in solids



# Other thoughts

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- Methane is explosive at 5-15%
- Does not work well with sand bedding but efforts are underway to solve this problem
- AD is a living system therefore you must be consistent
- Antibiotics (copper sulfate) can inhibit or kill microbial activity in digester

# Questions

- [www.bae.umn.edu/extens/manure/](http://www.bae.umn.edu/extens/manure/)



*University of Minnesota, Department of Biosystems and Agricultural Engineering*