ANAEROBIC DIGESTION

By

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Today's Discussion

- How Does Anaerobic Digestion Convert Biomass to Energy
- Forms of Biomass Typically Fed to Anaerobic Digesters
- Types of Digesters
- The Anaerobic Digestion Process
- Value Proposition of Anaerobic Digestion
- Future of Anaerobic Digestion
- Research Opportunities
- References

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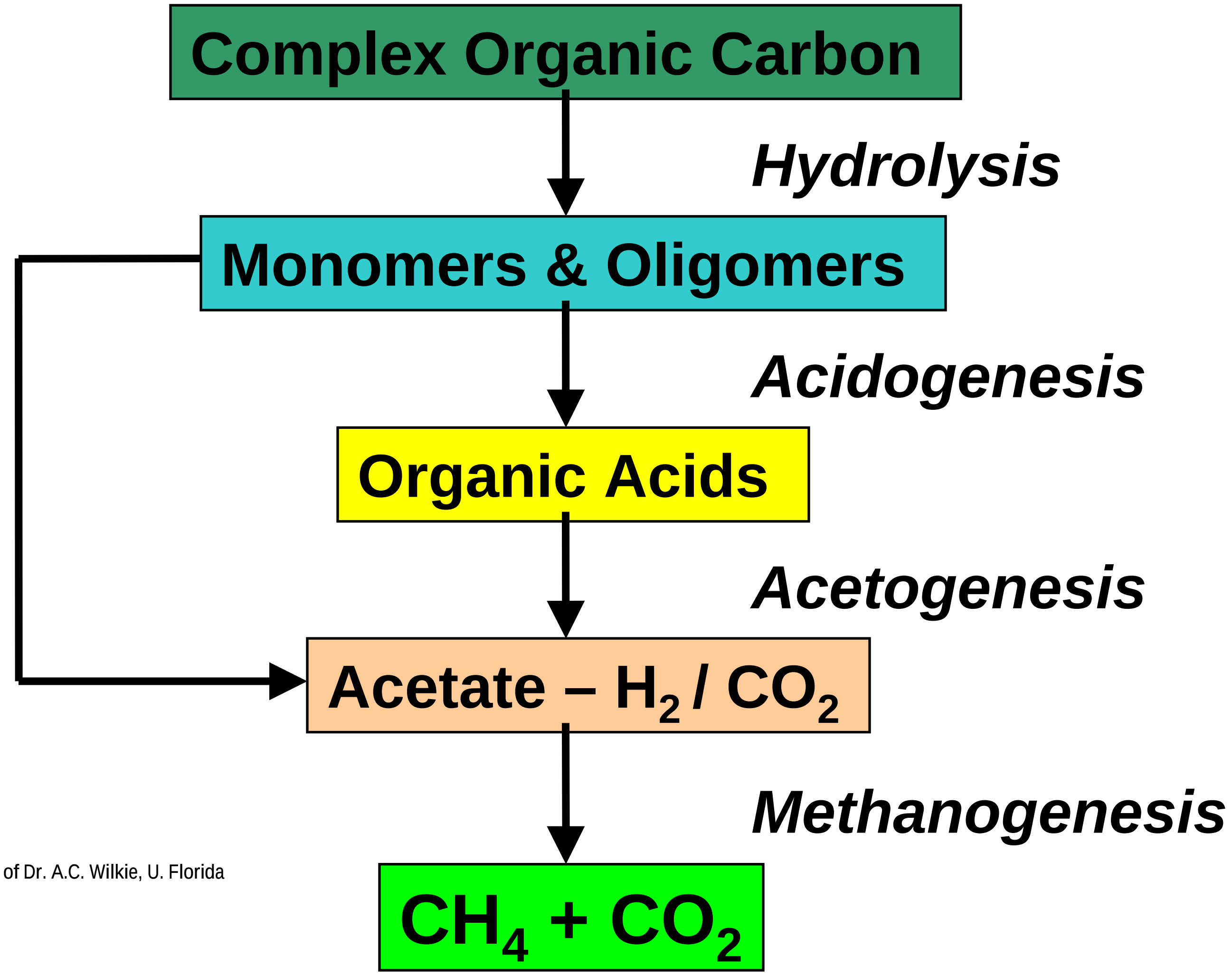
Converting Biomass to Energy



Courtesy of Dr. A.C. Wilkie, U. Florida

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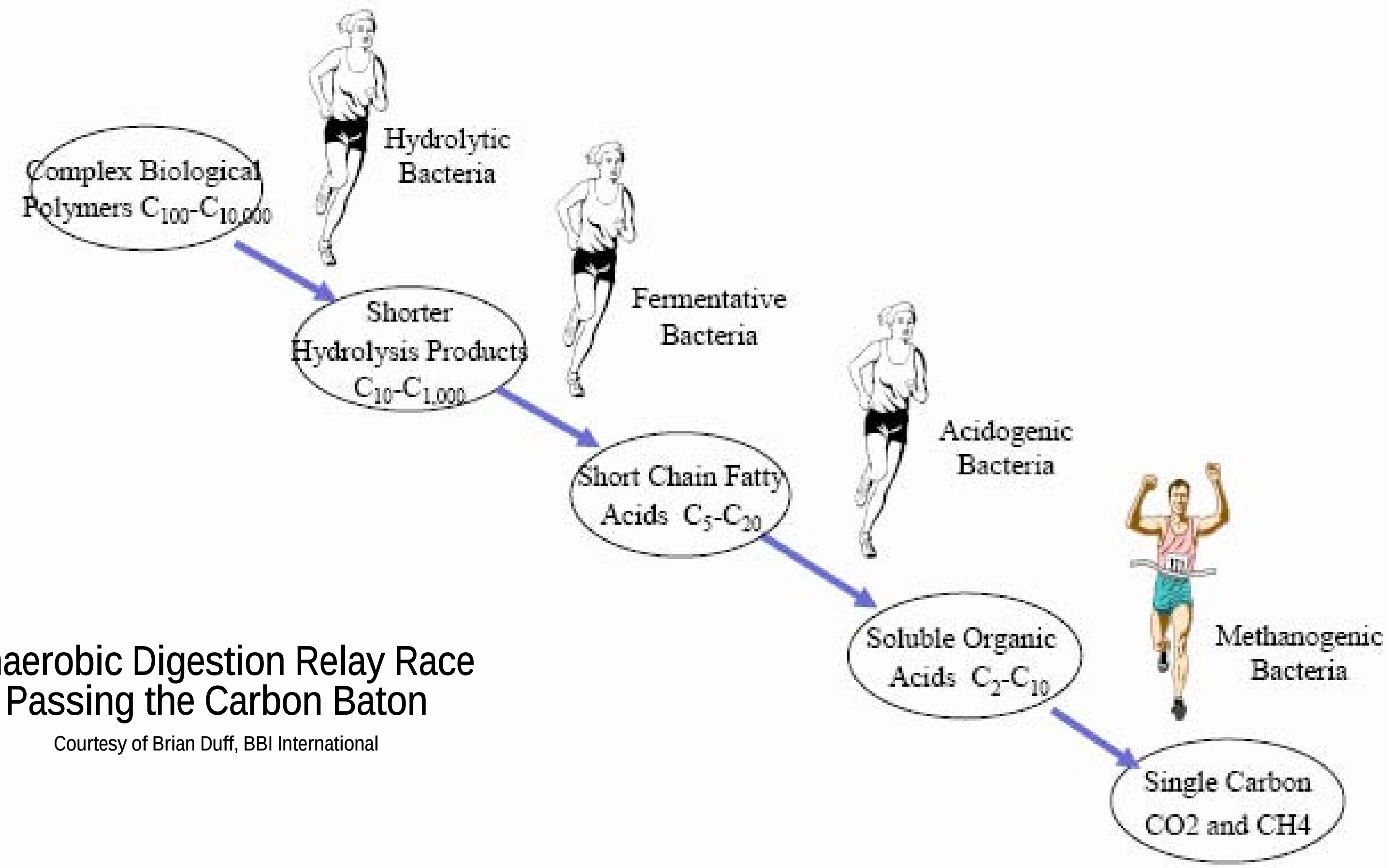
Converting Biomass to Energy



Anaerobic Digestion Relay Race
Passing the Carbon Baton

Courtesy of Brian Duff, BBI International

Converting Biomass to Energy

- *Hydrolysis* - Enzymes excreted by fermentative bacteria convert complex, heavy, un-dissolved materials (proteins, carbohydrates, fats) into less complex, lighter, materials (amino acids, sugars, alcohols...).
- *Acidogenesis* - Dissolved compounds are converted into simple compounds, (volatile fatty-acids, alcohols, lactic acid, CO_2, H_2, NH_3, H_2S) and new cell-matter.
- *Acetogenesis* – Digestion products are converted into acetate, H_2, CO_2 and new cell-matter.
- *Methanogenesis* - Acetate, hydrogen plus carbonate, formate or methanol are converted into CH_4, CO_2 and new cell-matter.

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Converting Biomass to Energy

Factors Controlling the Conversion of Biomass to Gas

The rate and efficiency of the anaerobic digestion process is controlled by:

1. · The type of waste being digested – Lignin, non-water soluble organics, nitrogen, sulfur
2. · Its concentration – typically 6 – 7 wt% for good digestion of most biomass
3. · Its temperature – Thermophilic 130 – 136 F, Mesophilic 95 – 100 F
4. · The presence of toxic materials – fungicides, antibacterial agents
5. · The pH and alkalinity – optimum 6.8 – 8.5 for methane production; indication of acid inhibition
6. · The hydraulic retention time – optimally set to ensure maximum solids conversion to gas
7. · The solids retention time – optimally set to sustain bacteria growth while converting solids to gas
8. · The ratio of food to microorganisms – no food, no bacteria growth
9. · The rate of digester loading – helps establishes digester size and F/M ratio
10. · The rate at which toxic end products of digestion are removed -

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What Biomass Is Consumed?

- More Traditional Feedstocks
  1. Agricultural Wastes
  2. Municipal Wastes
  3. Food Residuals and Processing Wastes
- Feedstocks of Growing Importance
  1. Industrial Wastes
  2. Ethanol Stillage
  3. Biodiesel Glycerin
  4. Other (i.e., Landfill Leachates)

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Digester types

- High Rate Reactors
  1. Packed Film Reactor
  2. Upflow Anaerobic Sludge Blanket (UASB)
  3. Horizontal Baffle Reactor (HBR)
  4. Completely Mixed Thermophilic Reactor (WVSU Pilot Plant)
  5. Contact Reactor
  6. Contactor Stabilization Reactors
  7. Acid Phased Reactors
  8. Temperature Phased Reactors

- Low Rate Reactors
  1. Anaerobic Covered Lagoon
  2. Completely Mixed Mesophilic Digester
  3. Plug Flow Digester

- Hybrids
  1. Contact/Fixed Film Reactor

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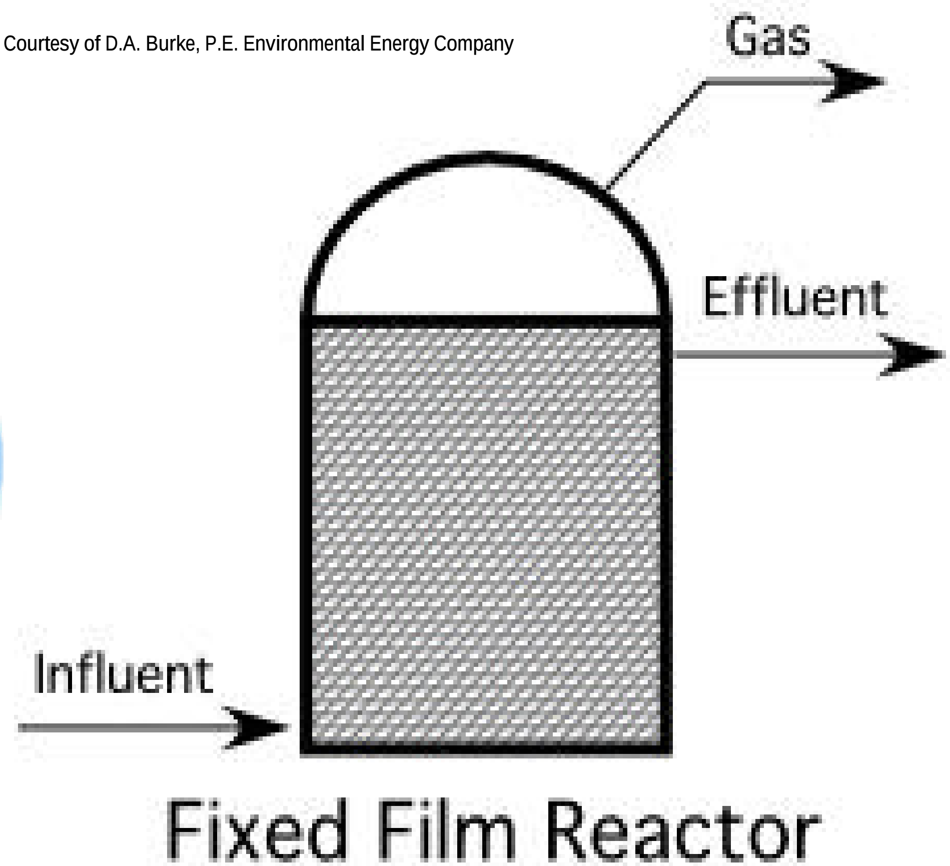
Digester Types

Courtesy of D.A. Burke, P.E. Environmental Energy Company

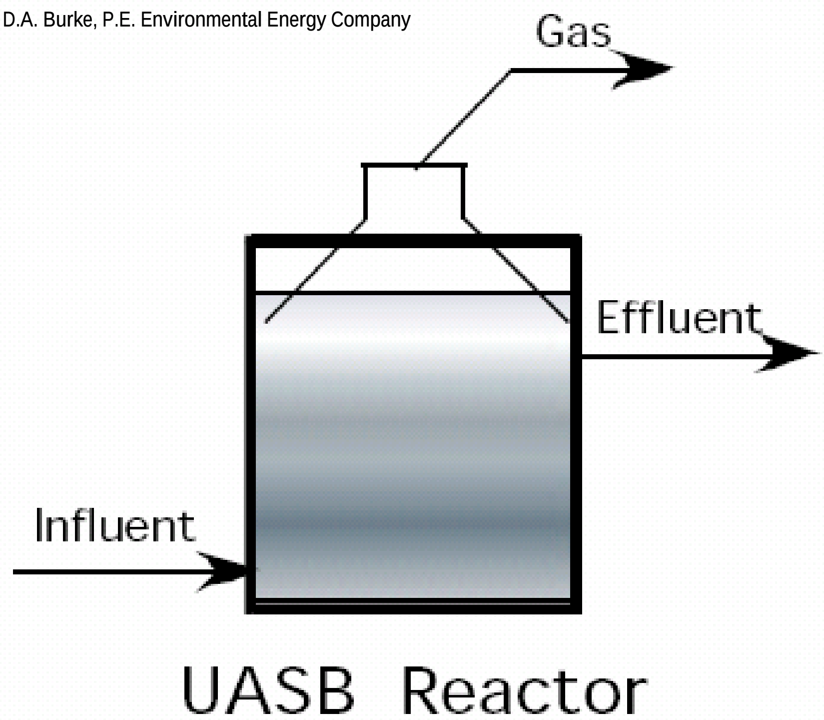


Packed Fixed Film Reactor

- Low retention times (e.g. 5 days)
- Temperature ambient to thermophilic
- Bacteria retained by reaction bed
- Feed washes past bacteria
- Pluggage a problem with high solids
- May be good fit for biodiesel glycerin

Digester Types

Courtesy of D.A. Burke, P.E. Environmental Energy Company



- Upflow Anaerobic Sludge Blanket Reactor
- Retention times very short
- Typically operated at ambient temperature
- Bacteria stored as granulated sludge
- Good at converting solubles to methane
- Maybe very suitable for biodiesel glycerin
- Conversion of high solids difficult

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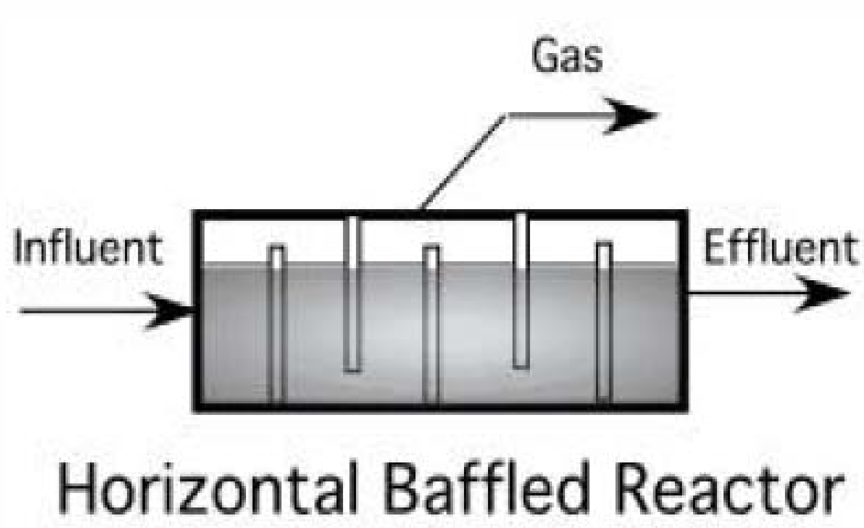
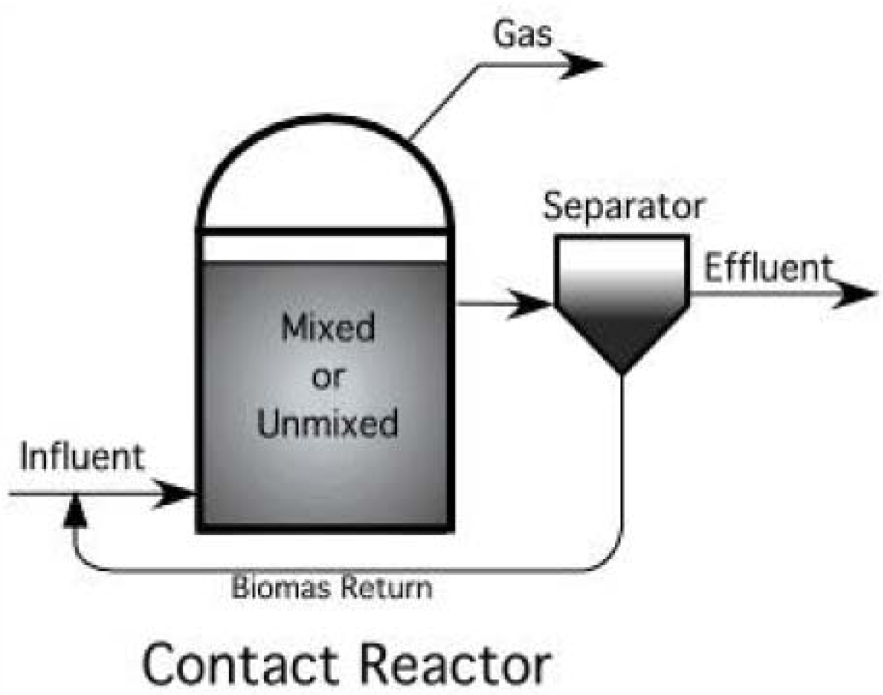


- Horizontal Baffled Reactor
- Horizontal version of USAB
- Low retention times
- Bacteria stored granulated sludge
- Pluggage common with high solids
- Good at converting solubles to methane
- Maybe very suitable for biodiesel glycerin
- Conversion of solids very difficult

Digester Types

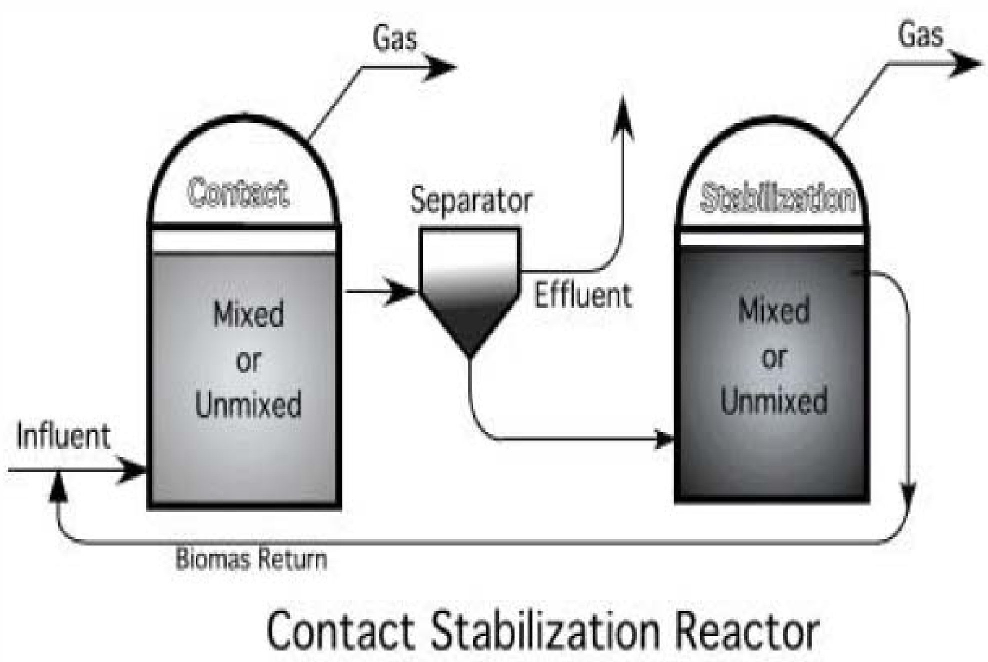
Courtesy of D.A. Burke, P.E. Environmental Energy Company



- Contact Reactor
- Low retention times
- Can be thermophilic or mesophilic
- Bacteria conserved by recycling solids
- Gravity Settlers usually sufficient
- Good solids conversion
- Higher biogas production

Digester Types

Courtesy of D.A. Burke, P.E. Environmental Energy Company



- Contact Reactor
- Low retention times
- Can be thermophilic or mesophilic
- Handles wide range of concentration
- Bacteria conserved by recycling solids
- Gravity Settlers usually sufficient
- Good solids conversion
- More efficient for digestion of cellulose
- Higher biogas production

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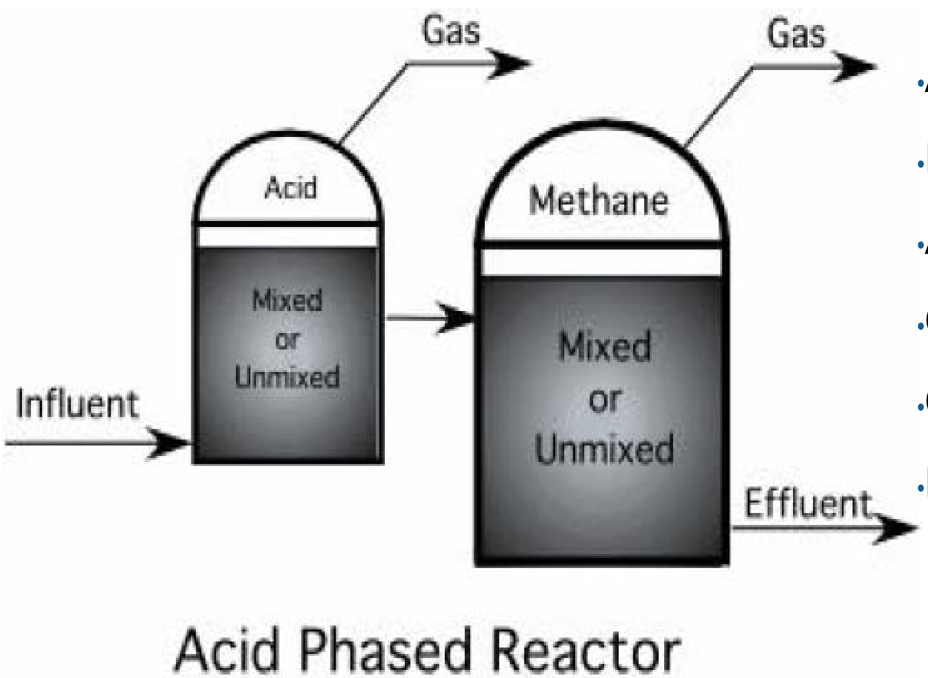
Digester Types

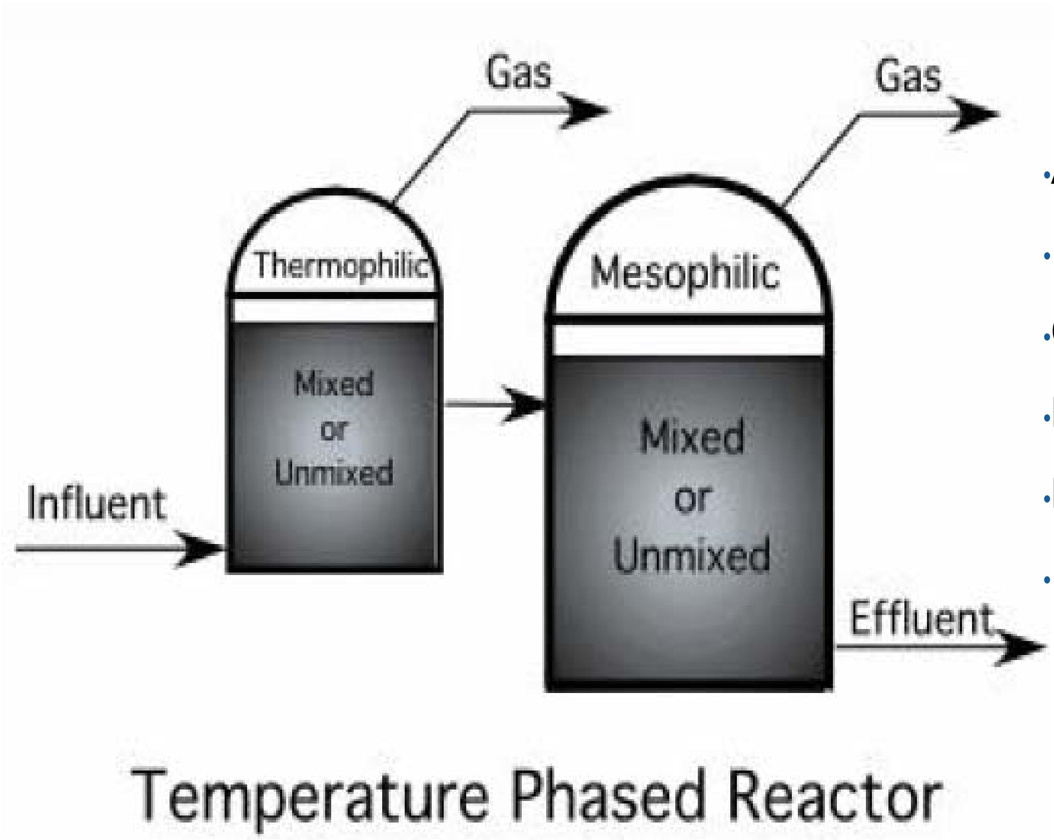
Courtesy of D.A. Burke, P.E. Environmental Energy Company



- Acid Phase Reactor
- Low retention times (especially Acid Reactor)
- Acid reactor smaller (faster growth)
- Can be thermophilic or mesophilic
- Good solids conversion
- Bacteria loss can be an issue

Digester Types

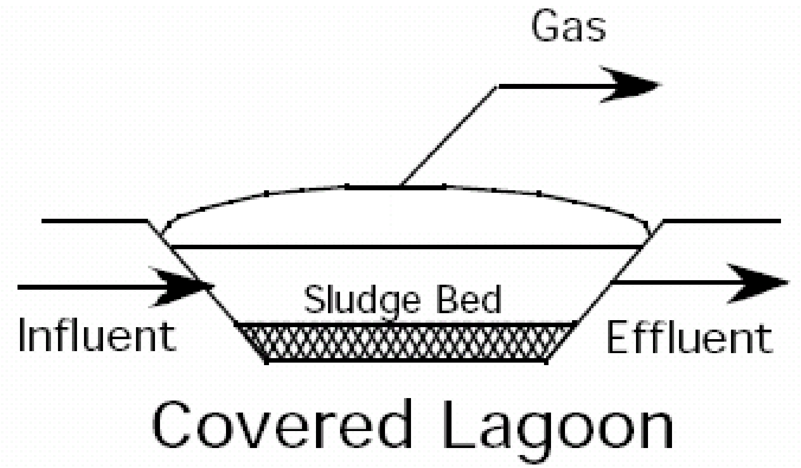
Courtesy of D.A. Burke, P.E. Environmental Energy Company



- Acid Phase Reactor
- Low retention times
- Good solids conversion
- More odor reduction
- More pathogen destruction
- Bacteria loss can be an issue

Digester Types

Courtesy of D.A. Burke, P.E. Environmental Energy Company



- Anaerobic Covered Lagoon
- Ground temperature usually
- Very high retention times
- Slow solids conversion
- Bacteria and liquid have limited contact
- Biogas production lower
- Very low capital approach
- Periodic cleaning is necessary

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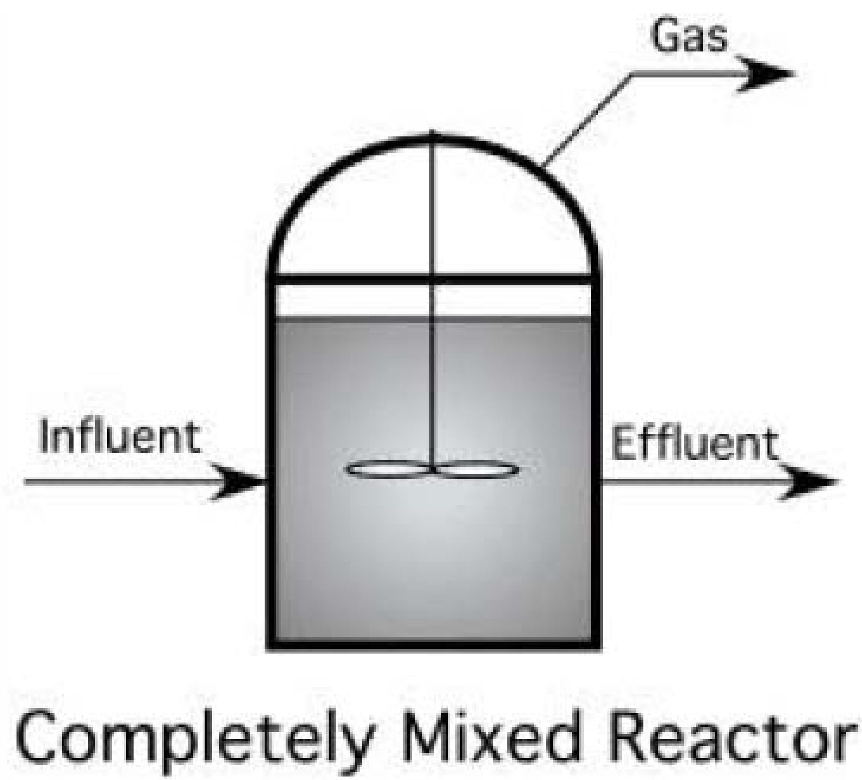
Digester Types

Courtesy of D.A. Burke, P.E. Environmental Energy Company



- Completely Mixed Digester
- Most common digester type used
- Reasonable retention times
- Can be thermophilic or mesophilic
- Mixing options typically available
- Handles wide range of concentrations
- Bacteria and liquid have very good contact
- Biogas production is very good
- Capital and energy cost is usually high
- Bacteria loss can be an issue

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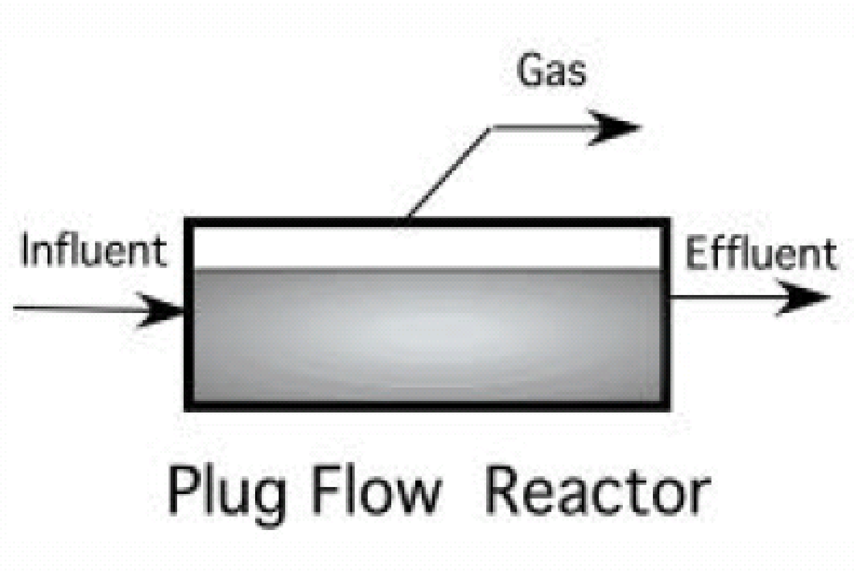
Digester Types

Courtesy of D.A. Burke, P.E. Environmental Energy Company



- Plug Flow Digester
- Simplest digester type used
- Reasonable retention times
- Can be ambient to thermophilic temperature
- Horizontal orientation mainly, but vertical too
- Slow solids conversion
- Biogas production is lower
- Bacteria loss can be an issue
- Periodic cleaning is necessary
- Very low capital cost

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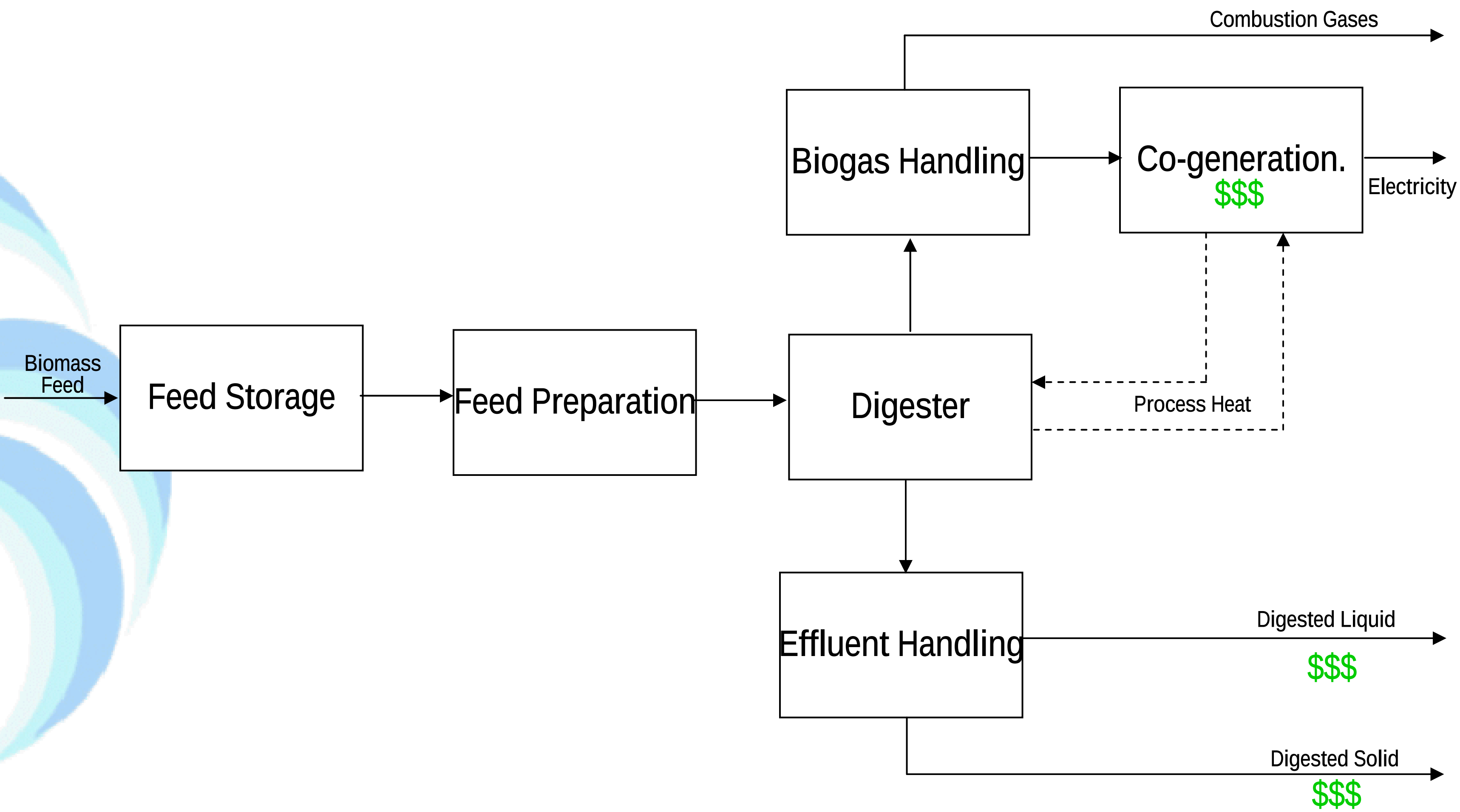
The Anaerobic Digestion Process



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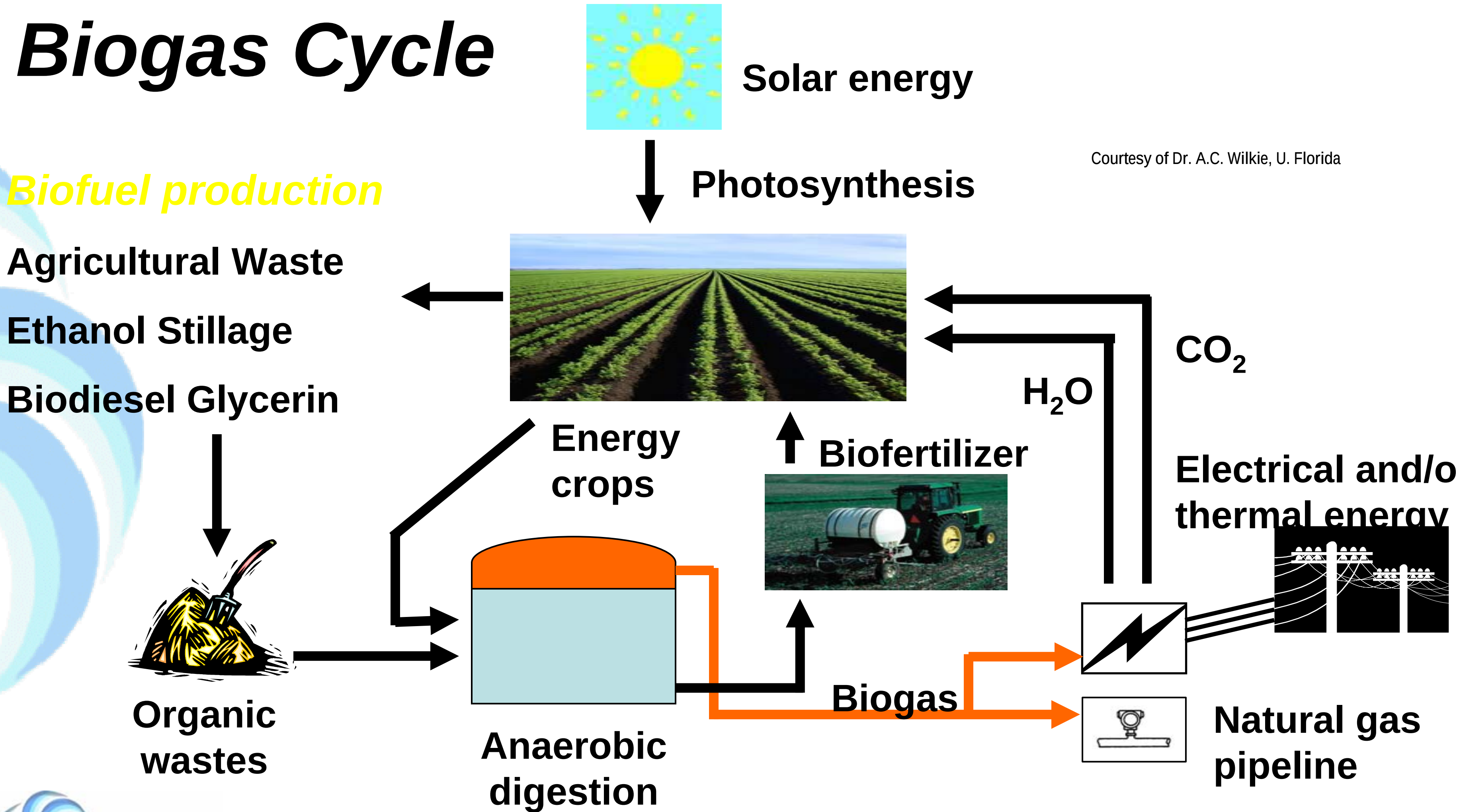
Value Proposition

Biogas Cycle



Value Proposition

- Biogas Production
  1. In plant or pipeline use
  2. 1 lb of volatile solid converted to gas that is utilized at 35% efficiency gives 0.58 Kwh
  3. Loading rates and the type of digester used greatly influence gas production
- Nutrient Management
  1. The type of Digester used will greatly influence the concentration of nutrients
  2. Reduction in pollution potential (phosphorous) and odor
  3. Without another value-added step, this will make or break most projects
- Pathogen Reduction
- Additional Substrate Processing
  1. Tipping fees
  2. Higher gas production
  3. Integration with other processes (ethanol, biodiesel, etc.,)

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Future of Anaerobic Digestion

- Expected to remain a mainstay of the agricultural industry. Land management will create opportunities to use more sophisticated processes however.
- Will continue to expand in the area of wastewater treatment especially industrial wastewater, and play an important role with municipal waste. The largest number of anaerobic digesters in the United States are in wastewater treating.
- As more ethanol and biodiesel capacity comes on line, opportunities to produce biogas from biomass generated from these processes on a larger scale will increase.
- Shift to more commercial size (versus farm size) digester processed expected as economics continue to improve. Corporate waste generators such as Cargill, Tyson, Excel, Seneca and Mapleleaf have already expanded their use of Anaerobic Digestion significantly.

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More Research Needed

Anaerobic Digestion research is very mature but still exciting:

1. Feed handling and preparation systems standardization (concentrate the important organics)
2. Impact of methanol on Anaerobic Disgestion of biodiesel glycerin
3. Fast reaction of biodiesel glycerin and ethanol stillage (in particular USAB Reactors)
4. Enzyme usage to possibly reduce retention times
5. Improvements in the integrity of microbial structures under various mixing conditions
6. Commercialization of technologies which have the most promise for the growing list of potential feedstocks, in particular cellulosics in high concentrations
7. Technology to produce more consistent and higher quality biofertilizers
8. Continued study of the synergistic effects of using aerobic and anaerobic digestion together.

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