Biogas from energy crops and biowastes

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Old technology - new application

- The technology of biochemical methane generation is well established
- Traditionally it has been used for waste stabilization
- Current focus is on energy production
- To be cost-effective in this role may require
  - engineering and technical improvements to increase conversion efficiencies
  - Selection and production of biomass feedstocks from a variety of sources
    - including novel and multi-use crops and agro-wastes from integrated farming systems, commercial and industrial wastes and by-products.
BIODEGRADABLE ORGANIC MATERIAL (CARBOHYDRATES, FATS, PROTEINS)

SIMPLE SOLUBLE ORGANICS

ACETIC ACID

ACETOCLASTIC METHANOGENIC BACTERIA

CH₄ + CO₂

PROPIONIC ACID BUTYRIC ACID LONG CHAIN VFA

ACETIC ACID

H₂ + CO₂

HYDROGEN-USING METHANOGENIC BACTERIA

HYDROLYSIS

ACID FERMENTATION

METHANOGENESIS
Anaerobic digestion in its simplest form

- Closed reactor
- System of gas collection
- Production of biogas
- Production of digestate
Product and Energy use

BIOMASS and AGRO-WASTE

Storage and pretreatment

DIGESTER

Gas engine turbine

Process heat
Space heat
Hot water

Electricity

CHP

Transport

Gas burner or boiler

Vehicle engine

Biogas storage

Biogas cleaning

Liquor

Fibre (straight to land)

Biogas reformation for fuel cell applications

Gas engine turbine

Process heat
Space heat
Hot water

Electricity

CHP

Transport

Gas burner or boiler

Vehicle engine

Biogas storage

Biogas cleaning

Liquor

Fibre (straight to land)

Biogas reformation for fuel cell applications
Process types

- Wet
  - One stage
  - Mesophilic
- Dry
  - Multi-stage
  - Thermophilic
Process differences

**Wet Process**
- less than 15% feedstock solids concentration
- one or several stages
- usually operate at 35°C
- requires water addition or recycle
- larger reactor
- proven technology for sewage sludge digestion
- more applicable to co-digestion with other waste

**Dry Process**
- more than 15% feedstock solids concentration
- usually one stage
- can operate at 35°C or 55°C
- minimal water addition
- smaller reactor
- becoming most popular choice for MSW
- more data and reference plants needed
Instantly recognisable!

Wet digester

mesophilic

Dry digester

thermophilic

Dry digester
Biogas as a renewable energy source

Crop and animal production
- energy crops and crop residues
- FYM & slurry

Anaerobic digester
- digestate

Processing plant
- residues
- transport

Heat and power
- gas
- transport fuel

CO₂
- Local housing, industry, commerce
- Local and national

Fuel, fertilizers, equipment
- CO₂
- CO₂
- CO₂

Transport
- analysis boundary
- analysis boundary
Energy models

- Database of energy inputs into the cultivation of different crop types established
- Factors affecting energy use in the process have been identified
- Equations developed to account for energy usage in the digestion process
- Energy usage model developed based on typical anaerobic digestion plant configurations and substrates
Phase separation innovations

Permeating beds

Plug flow reactors

Permeating bed

UASB or AF

Single stage

Two stage

Two phase systems (coupled and uncoupled)

Uncoupling of solids and liquid retention time

Hydrolysis and acidification reactor

Methanogenic reactor

Plug flow

Permeating beds

Two phase systems (coupled and uncoupled)
Permeating bed reactors

- Single bed systems using grass and maize have given poor results even with pH control.
- Permeating bed with second stage high rate methanogenic reactors gives greater potential for stable operation and biogas production.
- May be some potential for certain crop types but preliminary results indicate that overall process efficiency is likely to be poorer than for single phase mixed reactors.
- Potentially an interesting mix of fermentation products.
Plug flow systems

- Result from a high initial loading in the reactor
- Plug flow may limit the overall loading that can be achieved
- Interesting gas and acid production profile ($H_2$)
- May have potential for certain waste types and concept could be further exploited for refined fuel production and biorefinery intermediates
- Still to explore very high solids systems with high recycle rates
Two phase systems

- Overall performance for the treatment of market wastes at thermophilic temperatures and the loading used shows no advantage in process stability or performance compared to single phase controls.

- Uncoupling of solids and liquids retention time in a first phase mixed reactor using maize as a substrate failed to improve rates of hydrolysis and solids destruction.
Acknowledgements - Current project

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