Energy Resources

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Course Contents

- Introduction to Biomass Conversion
- Thermochemical Conversion of Biomass
- Pyrolysis
- Gasification and Combustion
- Biological Conversion of Biomass
- Biogas production and Ethanol Production
- Densification of Biomass
- Environmental Impacts

Today's Topic

- Characteristics of Biomass
- Introduction to Biogas
- Production of Biogas
- Important statistics

What is Biomass?

- Any organic material derived from plants (botanical) or animals (biological)
- A non-fossilized fuel source that is biodegradable
- Excludes materials normally used as foods

A Renewable Energy Source

- When biomass dies it is naturally broken down and releases H_2O, CO_2, and energy
- The same change happens when used for chemical or energy purposes
- Net pollution contribution is zero!

How is Biomass Formed?

- Botanical (plant) biomass converts CO_2 and H_2O to carbohydrate and oxygen with energy from the sun through photosynthesis
- Biological (animal) species grow by consuming botanical species or other biological species

Biomass Classification

A. Virgin Biomass

1. Terrestrial
   - Forest
   - Grasses
   - Energy crops
   - Cultivated crops
2. Aquatic
   - Algae
   - Water plants

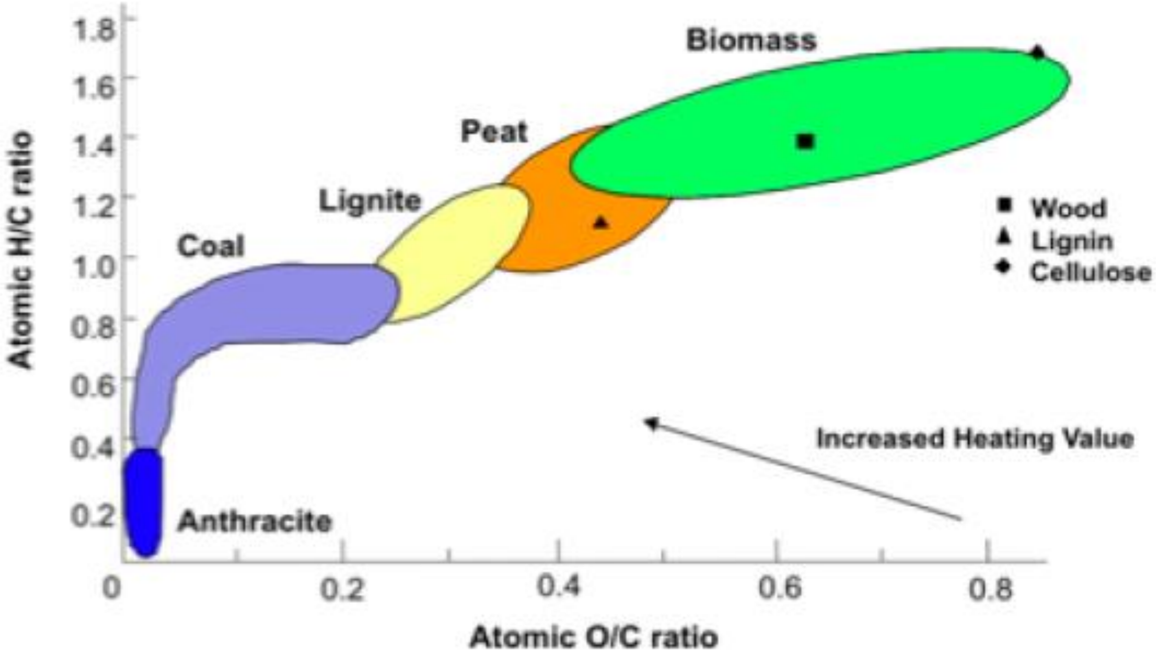
Biomass Classification

B. Waste Biomass

1. Municipal waste
   - Municipal solid waste
   - Bio-solids, sewage
   - Landfill gas
2. Agricultural solid waste
   - Livestock and manures
   - Agricultural crop residues
3. Forestry residues
   - Bark, leaves, floor residues
4. Industrial wastes
   - Demolition wood, sawdust
   - Waste oil, fat

Classification of Biomass Fuels

1. **Atomic ratios**
   - H:C:O content
   - van Krevelen diagram (H/C versus O/C)



Physical Properties of Biomass

- True density

$$\rho_{true} = \frac{\text{total mass of biomass}}{\text{solid volume in biomass}}$$

Physical Properties of Biomass

- True density
- Apparent density

$$\rho_{apparent} = \frac{\text{total mass of biomass}}{\text{volume of solids and internal pores}}$$

Physical Properties of Biomass

- True density
- Apparent density
- **Bulk density**

$$\rho_{bulk} = \frac{\text{total mass of biomass particles or stack}}{\text{bulk volume occupied by particles or stack}}$$

Thermodynamic Properties of Biomass

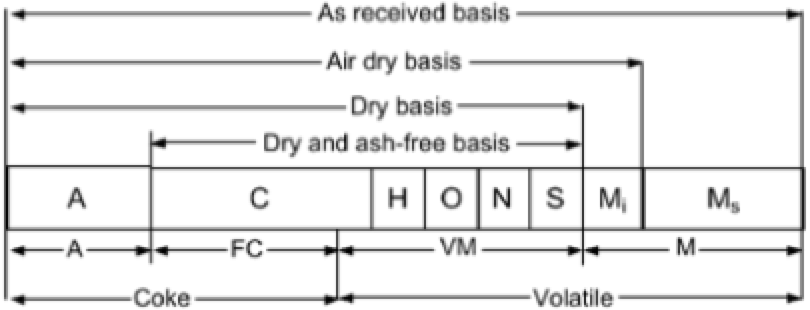
- Thermal conductivity
  - The ability of the biomass to conduct heat
- Specific heat
  - The amount of heat required to raise a unit mass of biomass by one unit of a specified temperature
- Heat of formation
  - Energy to form the biomass from its constituent elements

Thermodynamic Properties of Biomass

- Heat of combustion
  - Heat released/absorbed in a chemical reaction without a change in temperature
- Ignition temperature
  - The temperature of the biomass at which the combustion reaction becomes self sustaining
- Heating value
  - HHV – heat released by combustion of a fuel at 25°C and returned to 25°C
  - LHV – heat released by combustion of a fuel at 25°C and returned to 150°C
  - LHV = HHV – latent heat of vaporization

Other Properties of Biomass

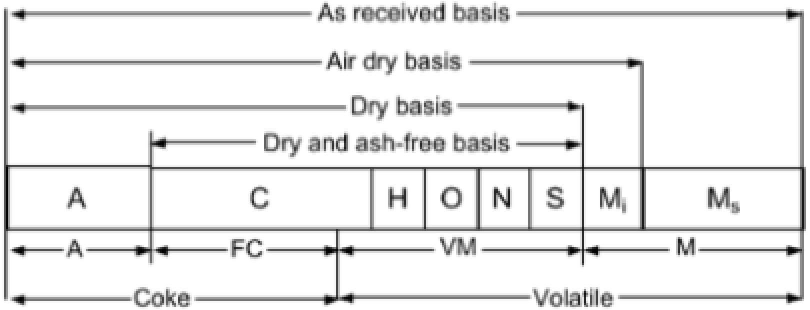
- Bases of expressing biomass composition
  - "As received" basis
    - Ultimate analysis
      - Determines the composition of the biomass fuel in terms of basic elements
      - C + H + O + N + S + A + M = 100%



A – Ash	H – Hydrogen	C – Carbon
O – Oxygen	N – Nitrogen	S – Sulfur
M_i – Inherent Moisture	M_s – Surface Moisture	

Other Properties of Biomass

- Bases of expressing biomass composition
  - "As received" basis
    - Proximate analysis
      - Determines the composition of the biomass fuel in terms of gross components
      - VM + FC + A + M = 100%



A – Ash	H – Hydrogen	C – Carbon
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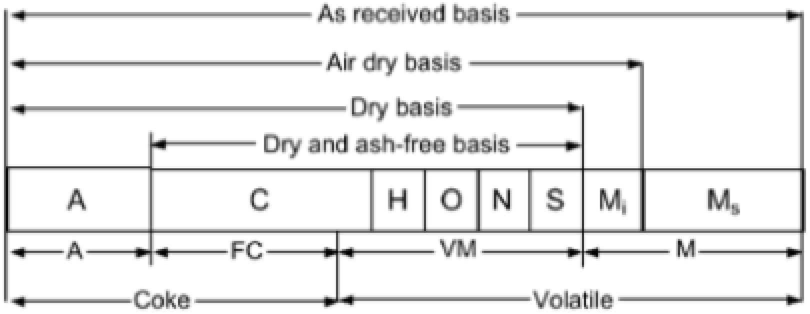
Other Properties of Biomass

- Bases of expressing biomass composition
  - "As received" basis
  - "Air dry" basis
    - The biomass is dried in air, removing surface moisture



A – Ash	H – Hydrogen	C – Carbon
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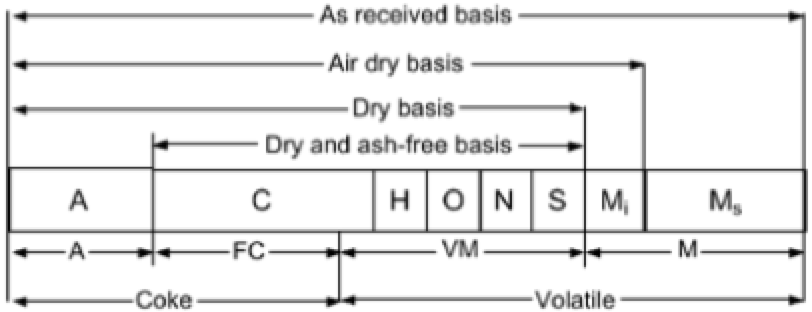
M_i – Inherent Moisture	M_s – Surface Moisture	

Other Properties of Biomass

- Bases of expressing biomass composition
  - "As received" basis
  - "Air dry" basis
  - "Dry" basis
  - "Dry and ash free" basis
    - Components are reported with ash and water removed



A – Ash	H – Hydrogen	C – Carbon
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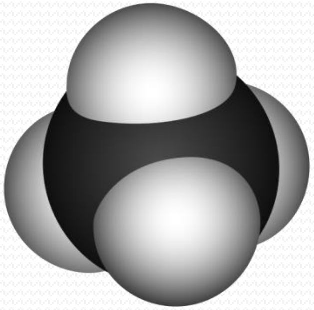
Conclusions

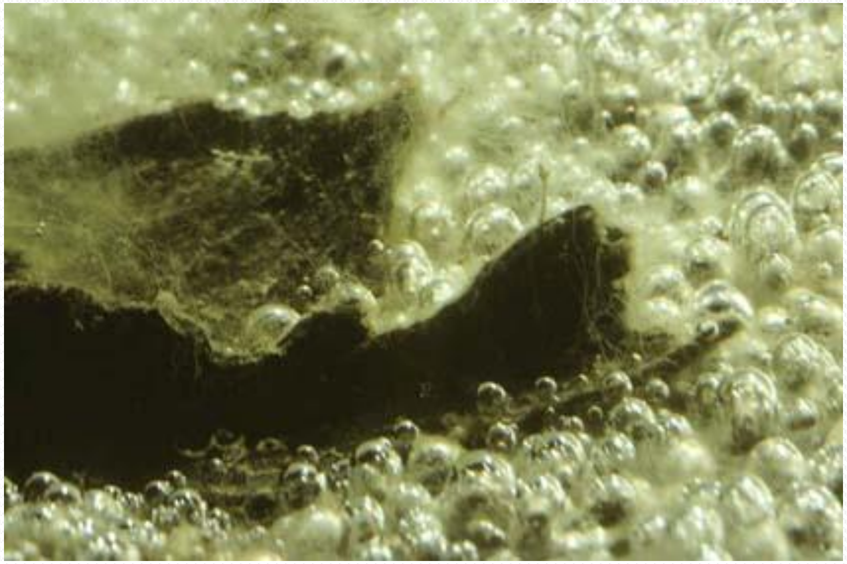
- Biomass is a renewable and sustainable alternative to fossil fuels
- There is no net pollution to the environment
- Classification of Biomass
- Properties of Biomass
  - Physical
  - Thermodynamic
  - Other

What is biogas?

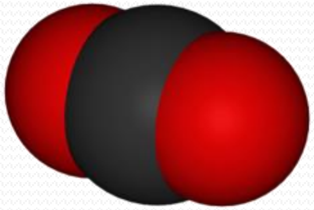
- A mixture of methane and carbon dioxide



CH_4



CO_2



What is this?

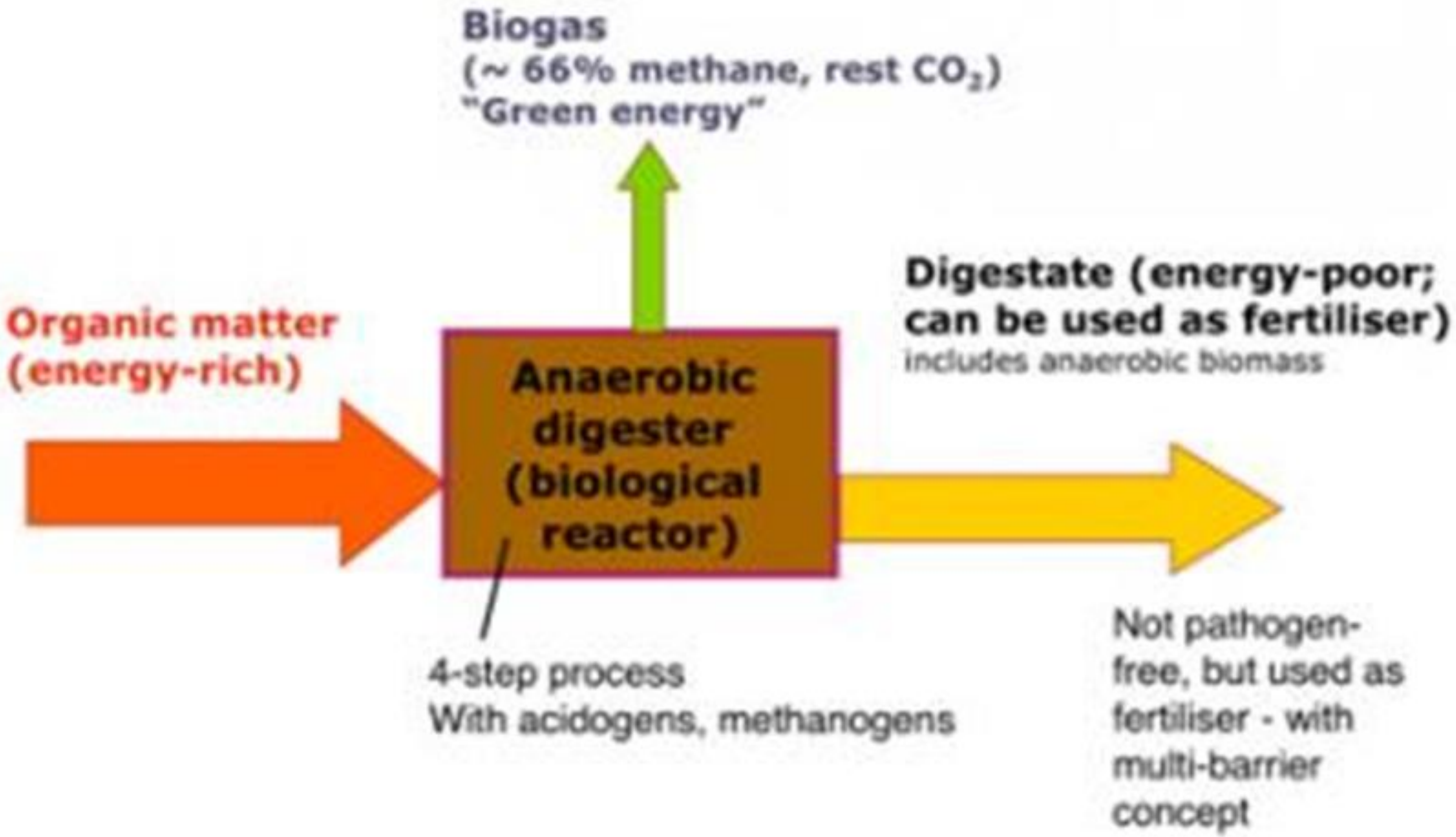
- Methane or 'swamp gas', produced naturally in swampy ponds

What is Biogas?

- It is similar to natural gas.
  - 50-70% methane;
  - 30-40% carbon dioxide;
  - Insignificant amounts of oxygen and hydrogen sulfide (H_2S).
  - Biogas burns without soot or ash being produced
  - Methane is a combustible gas

- Methane is the important product. It can be burned as fuel, just like natural gas.

Anaerobic Digestion in a Diagram



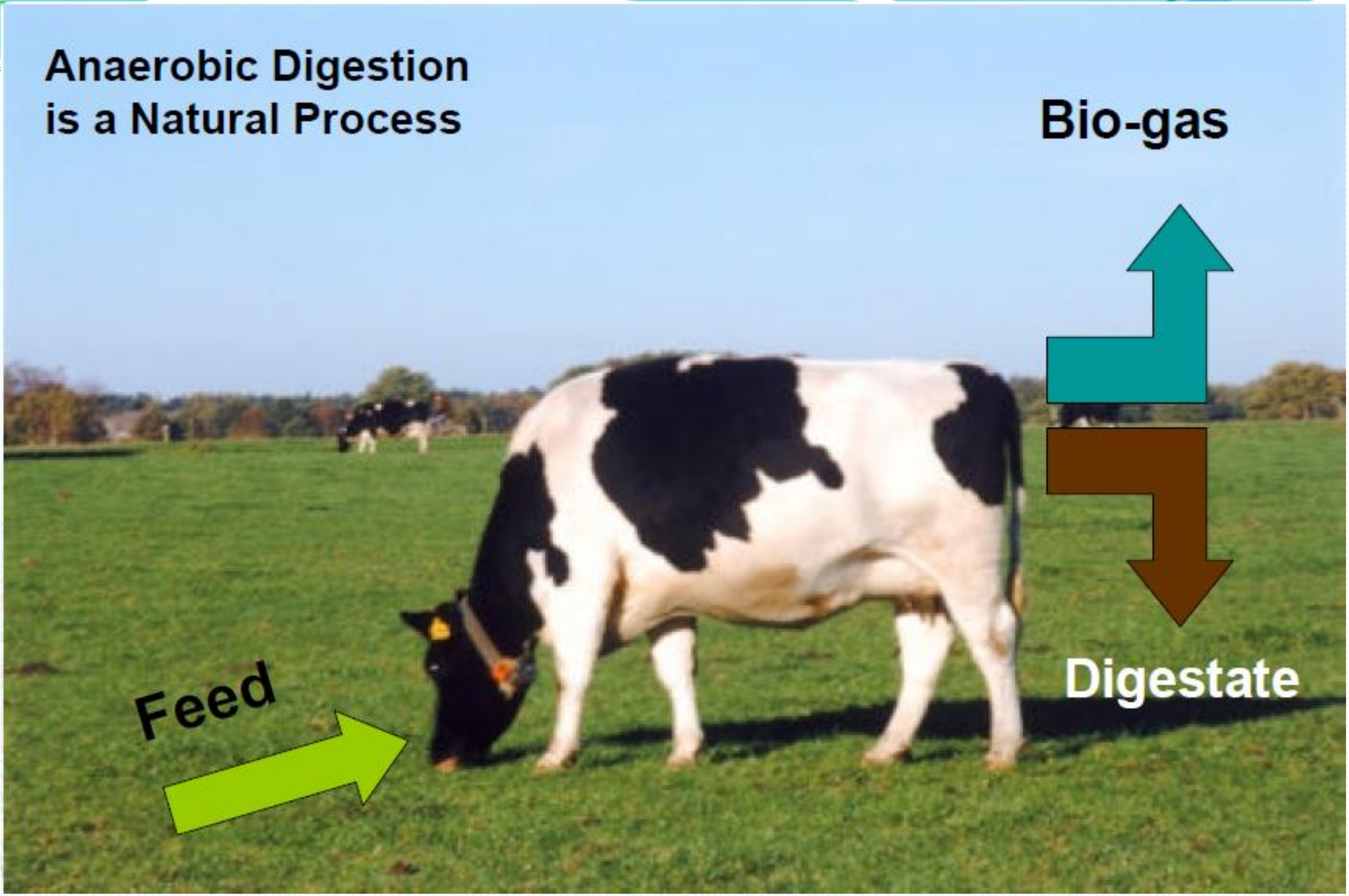


Image courtesy of Community Composting Network

What is it used for?

- Biogas is a fuel used as an energy source for light, heat or transportation

How is it made?

Biogas is produced by the breakdown of organic waste by bacteria without oxygen (**anaerobic digestion** or fermentation).

Leftover food from houses, shops, restaurants and factories

Cow, sheep and chicken manure

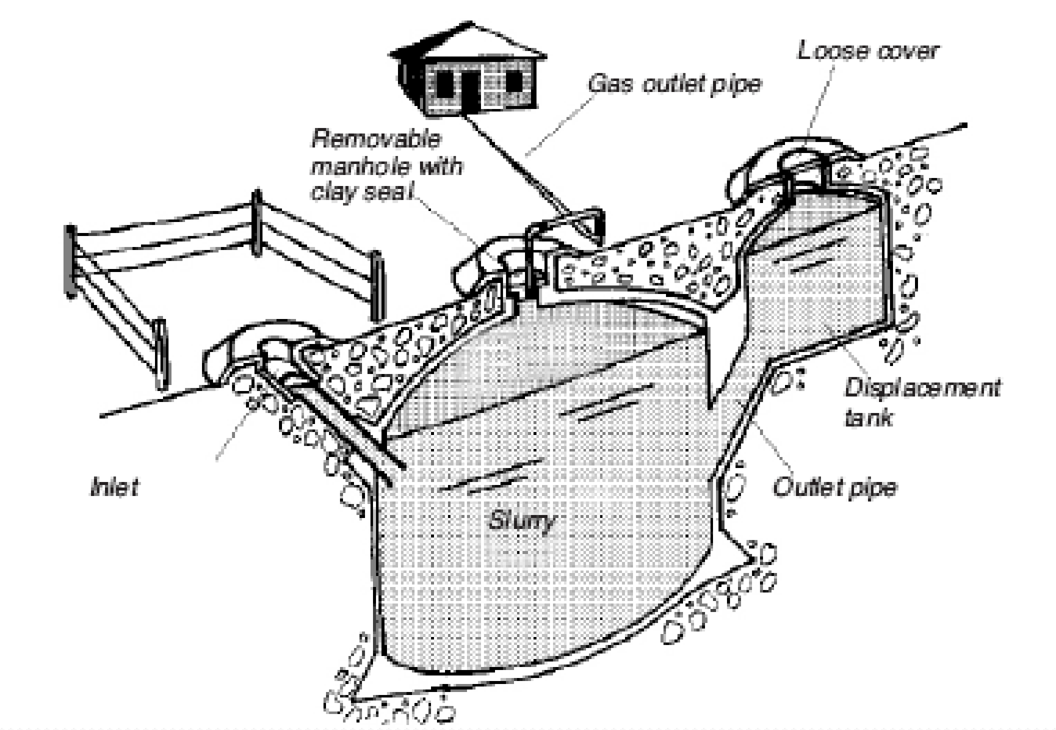
Sewage

Leftover straw and crops from farming

Leftover meat and blood from abattoirs

How is it made?

Biogas is made by fermenting organic waste in a **biogas digester.**



Digesters vary from small household systems…

….to large commercial plants of several thousand cubic metres

Holsworthy Biogas Plant, Devon

- It can also be captured from landfill sites where organic waste has been rotting under the ground

History of Biogas

- One of the oldest forms of renewable energy
- Marco Polo mentioned the use of the technology. Probably goes back 2000-3000 years ago in ancient Chinese literature
- The earliest evidence of use in Assyria (10^{th} century BC)

History of Biogas

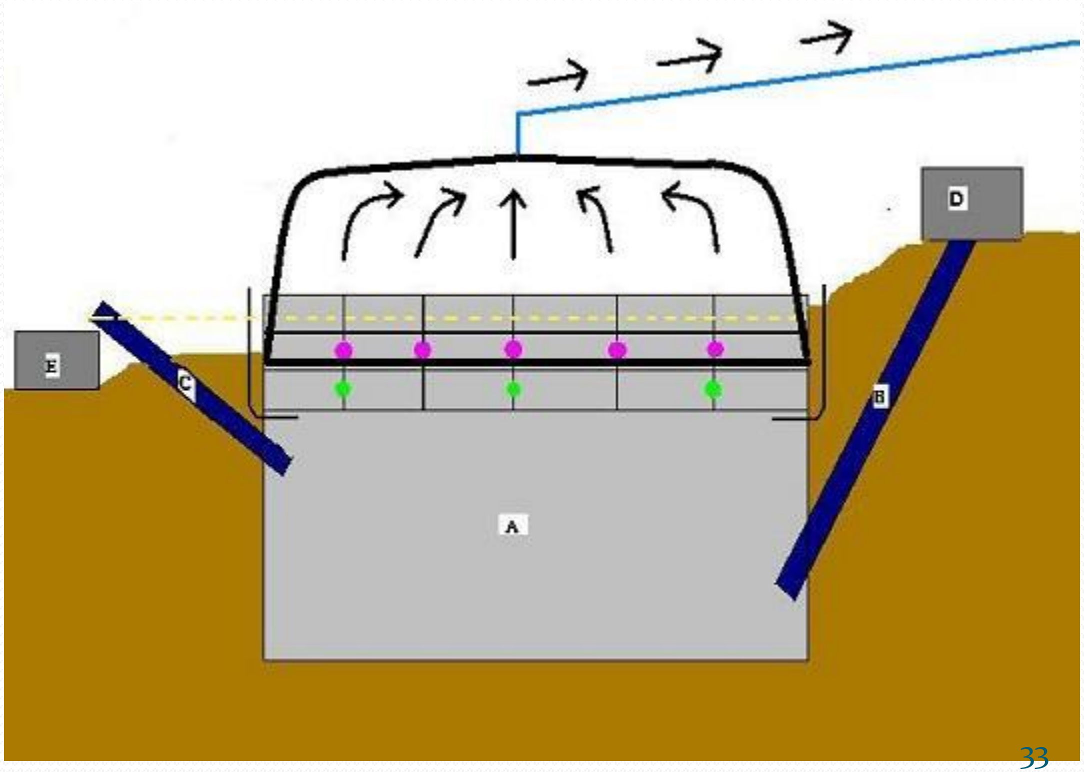
- Jan Baptita Van Helmont determined in 1630 that flammable gases could evolve from decaying organic matter.
- Anaerobic digestion first described by Benjamin Franklin 1764.
- Count Alessandro Volta in 1776 found a correlation between amount of decaying organic matter and amount of flammable gas produced.
- In 1808, Sir Humphrey Davy determined that methane was present in the decay process.

History of Biogas Cont'd

- First digestion plant was built in 1859 in Bombay, India for a leper colony
- Exeter, England, in 1895: biogas used to power street lamps
- 1920's and 30's interest in anaerobic digestion increased

Examples of Digesters Around the World

Costa Rica



Digesters Around the World (cont'd)

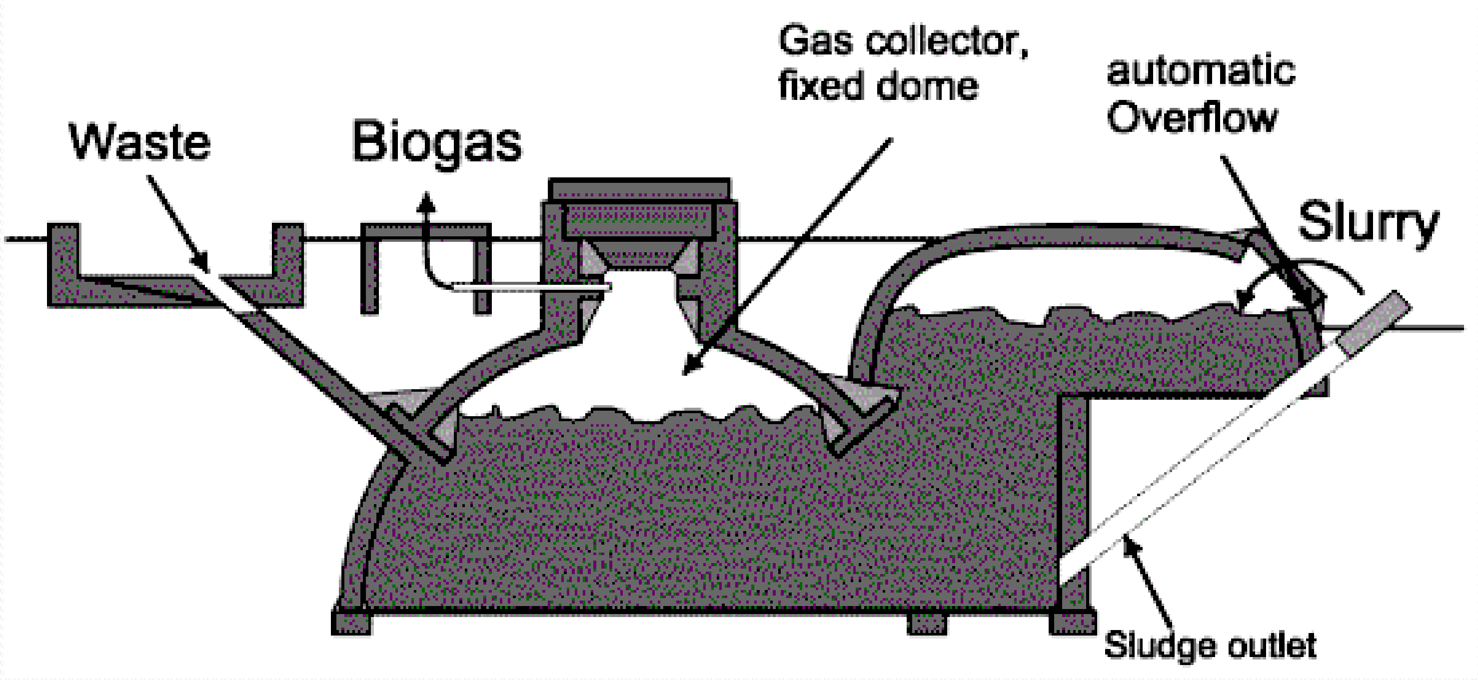
India (ARTI)

Digesters Around the World (cont'd)

United States

Digesters Around the World (cont'd)

Digester (used in India and China)



What Type of Waste Produces Biogas?

- Any organic waste can produce biogas
- Human, manure, fruit and vegetable waste

What Type of Waste Does NOT Produces Biogas?

- Fiber rich waste such as wood, leaves, etc. are difficult to digest
- Heavy metals
- Inorganic materials in high concentration (Nitrate, Sodium, Sulphate, Sodium, Potassium, Calcium, Magnesium, etc)

How Much Biogas Can I Get From My Waste?

- Amount of biogas depends on the waste itself and design of the digester.
- Some digesters can yield 20 liters of biogas per kilogram of waste up to 800 liters per kilogram.
- Factors: waste quality, digester design, temperature, system operation, presence of oxygen.

How Much Energy is in Biogas?

- Average fuel value of methane = 1000 BTU/ft3
- Average fuel value of propane = 2500 BTU/ft3
- 1 BTU/ft3 = 37.2589 KJ/m3

How Much Energy is in Biogas?

- Therefore, using the SI system, Fuel Value units:

- FV methane = 1000 * 37.2589 KJ/m3 = 37258.9 KJ/m3
- FV propane = 2500 * 37.2589 KJ/m3 = 93147.3 KJ/m3
- FV propane / FV methane = 2.5

- When both fuels are burned completely, propane produces 2.5 times more energy per unit of volume.

How Much Biogas Do I Need?

- For Example: We want 40 lbs of propane-equivalent per week.
- Biogas is 50-70% methane, 30-50% CO_2 and 5-15% N_2, H_2, etc.
- 40 lbs propane * 2.5 = 100 lbs of methane
- 100 lbs of methane / 60% = 166.67 lbs of biogas

Obstacles

- Economic: Keeping it inexpensive
- Time
- Equipment: Limited
- Weather: When it rains, it pours!

Problem Solving

- Recycled materials
- Solve energy crisis

Thank You