IMPACT LABS NIGERIA

BIOMASS

AN INTRODUCTION

WHAT IS IT?

- Biomass: Organic materials that contain stored energy
  - This is considered to be a renewable energy source, because we can always grow more trees and plants, and waste will always exist

- Law of Conserved Energy:

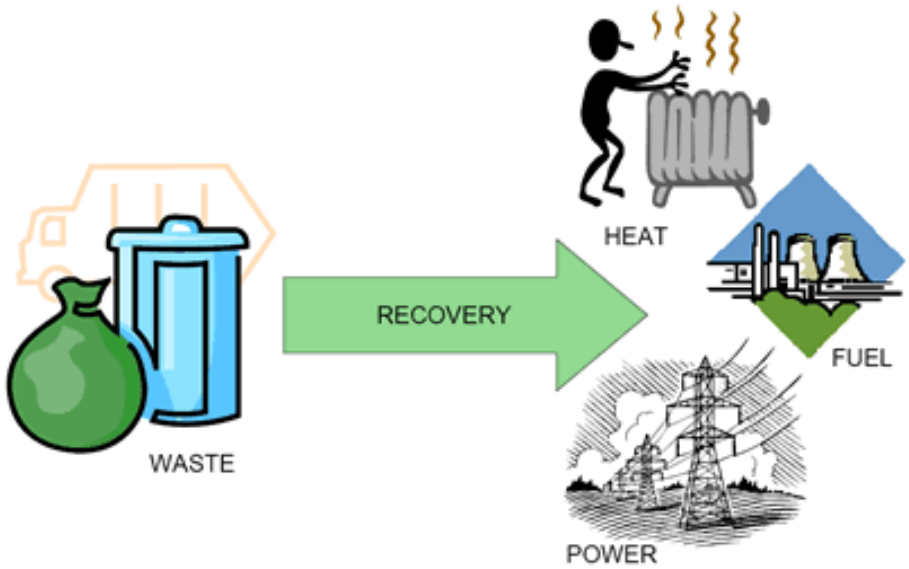
  dQ= dU +dW (equivalently, dU=dQ-dW)

  - dQ = Energy added to system by heating,
  - dU = change in the Internal Energy of system
  - dW= Energy lost to system by work

HOW DO WE GET ENERGY FROM BIOMASS?

Photosynthesis	▪ Plants convert energy from the sun into chemical energy in the form of glucose ▪ $6CO_2 + 6H_2O \Longrightarrow C_6H_{12}O_6 + 6O_2$
Burning	▪ Wood ▪ Garbage Waste
Conversion to other energy forms	▪ Methane gas ▪ Transportation fuels ▪ Ethanol: ferment corn and sugar cane ▪ Biodiesel: made from left-over food products like vegetable oil and animal fat

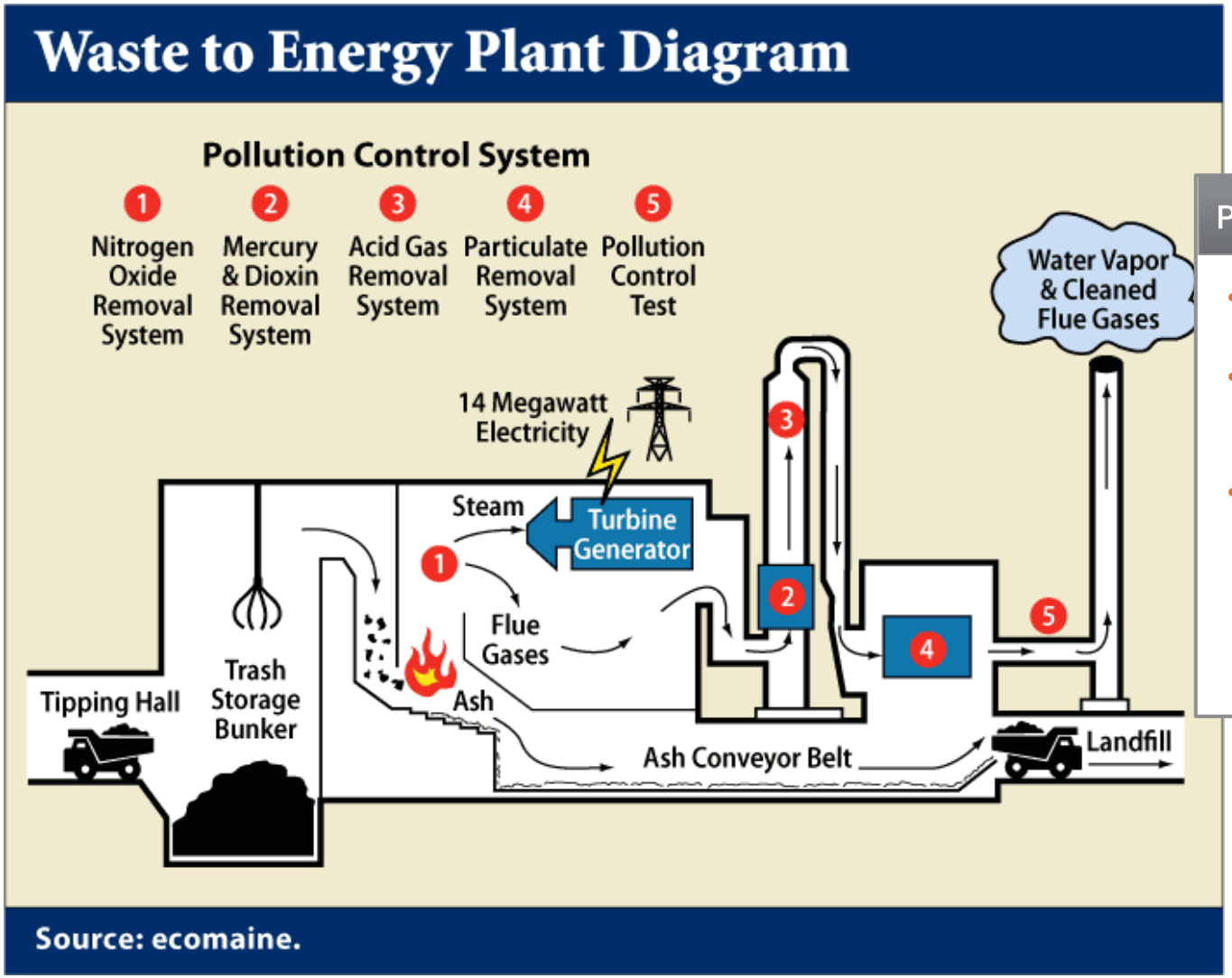
EXAMPLE: WASTE-TO-ENERGY



Potential energy outputs

- **Fuel:** paper, cardboard, food scraps, grass clippings, leaves, plastics, non-combustible materials, synthetic material made from plastics
- **Steam and Electricity:**
  - Burning fuel --> steam --> heats buildings, generate electricity
  - Decompose material --> methane gas --> electricity
- **Heat:** Burning waste decreases amount in landfills and generates heat

WASTE TO ENERGY (CONT.)

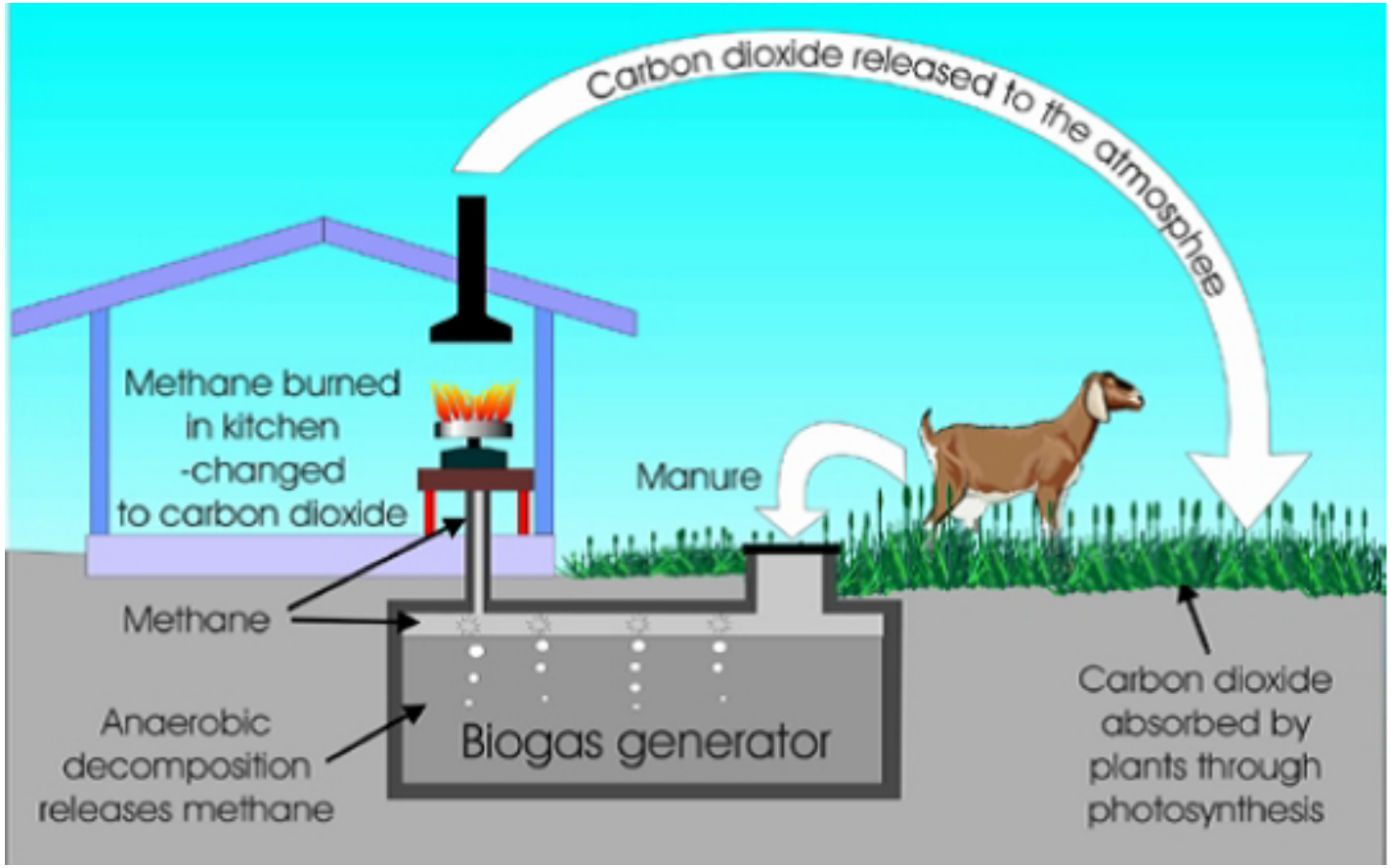


Potential energy outputs

- Sources: Manure, cellulose, food
- Conversion takes place in landfills or biogas generators
- Example:
  - Animal waste + water + rotting vegetation --> bacteria--> methanol gas --> fertilizer

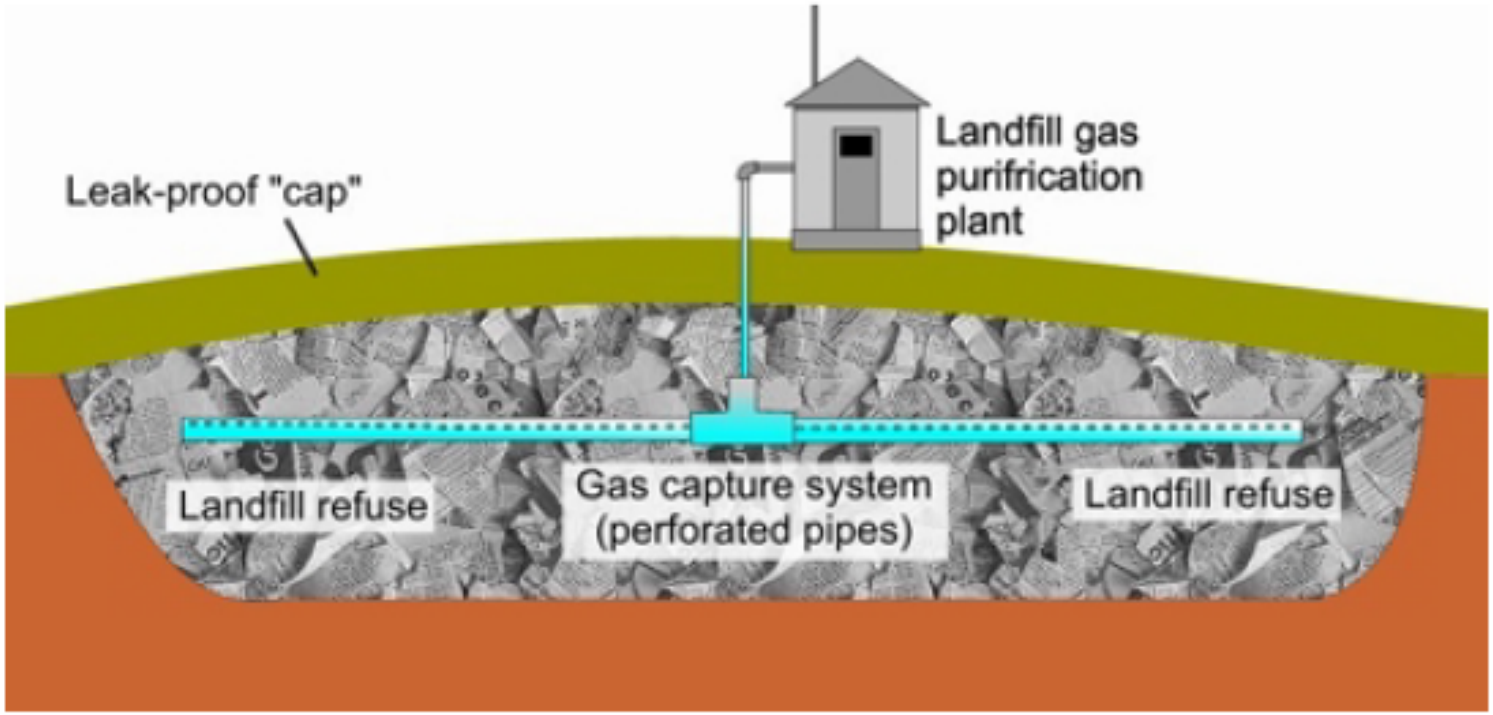
BIOMASS IN TECHNOLOGY

- Biogas Generator (Animal Waste, Burning)



BIOMASS IN TECHNOLOGY (CONT'D)

- Biogas generator (Landfill)



BIOMASS: GOOD OR BAD?

PROS

- Renewable: organic waste is made every day
- Reduced solid pollution
- Reduce carbon emission
- Briquettes used for electricity cleaner
  - *Briquettes:* flammable materials to start and maintain fires
- Cost-Effective
  - No large pipelines are need
  - Energy is used and supplied in the same area
- Produces 10 times more energy than sun or wind

CONS

- Destruction of the Ozone Layer --> Global Warming
  - Carbon-Dioxide, Methane, Nitrous Oxide, etc.
- Releases high levels of gases, contributing to Global Warming
- Extraction process is expensive
- Process of harvesting, storing, and building up a supply of the materials is significantly more expensive than fossil fuels
- Power plants take up excessive space and use large amounts of water

BIOMASS IN NIGERIA

Sources of energy consumption in Nigeria

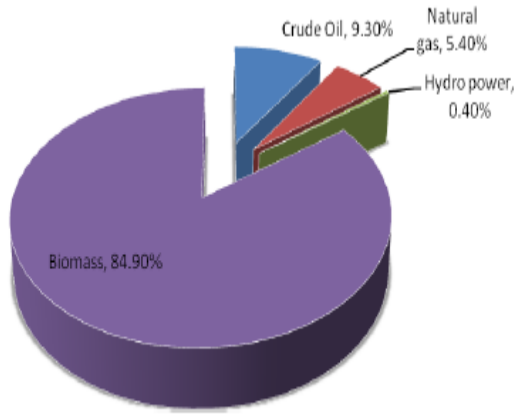


Figure 1. Energy consumption in Nigeria, 2009. Source: IEA (2012).

- In Nigeria, agriculture is the largest sector of the economy
  - It contributes to 70% of the nation's employment
  - It makes up 40% of the nation's Gross Domestic Product (GDP)
- 84.9% of the energy in Nigeria is consumed in the form of Biomass
  - Agricultural Crops
  - Wood
  - Charcoal
  - Grasses and Shrubs
  - Residues and Wastes (agricultural, forestry, municipal, and industrial)
- Biomass accounts for over 90% of the domestic energy needs of over 70% of the nation's population, mostly residing in rural areas and peri-urban centers

IMPACT LABS NIGERIA

BIOMASS

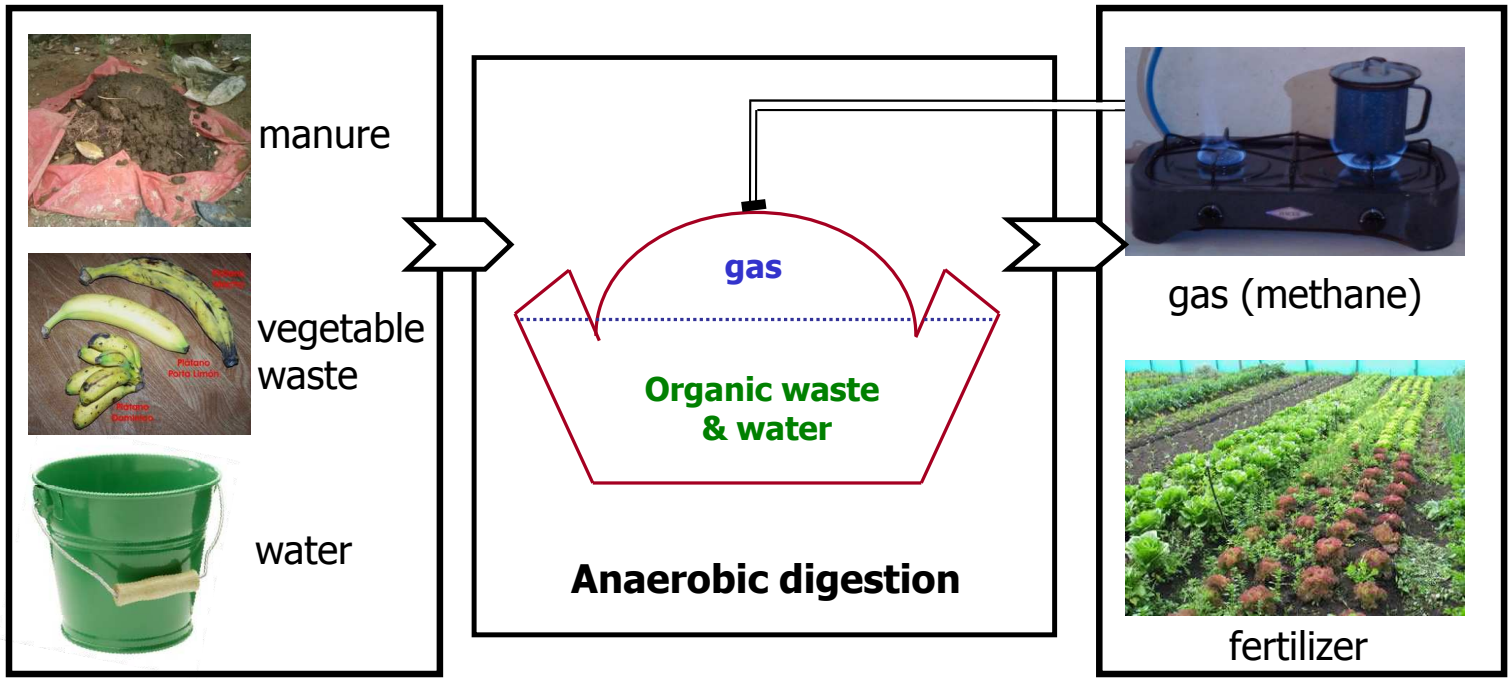
BIOGAS AND BIODIESEL PRODUCTION

BIOGAS

- Objectives:
  - How biogas digesters work
  - When and where they are appropriate
  - Important design considerations
  - Build a small scale demo

WHAT IS A BIODIGESTER?

A biodigester transforms animal manure and vegetable waste into gas for cooking and fertilizer for the crops



BIOGAS

Uses

- On-site methane
- Electricity generation
  - On-site
  - Grid
- Fertilizer
- Waste management (example: slaughterhouses)

Properties

- Methanogens (methane-producing bacteria) breed in slightly alkaline environment and prefer 37 °C.

No O_2

- Water covering inlet and outlet prevents O_2 from entering system. Keeps it anaerobic.

Constant temp. (30 – 40 °C)

Constant pH (6.8 – 7.5)

- Determined by feedstock
- C:N ratio must balance
- Too much N produces too much ammonia, which raises pH too high

BIOGAS

Bacteria produce methane under anerobic conditions

Scanning electron microscope images of B. thetaiotaomicron, a prominent human gut bacterium, and the intestine. From: Human Gut Hosts a Dynamically Evolving Microbial Ecosystem Gross L PLoS Biology Vol. 5, No. 7, e199 doi:10.1371/journal.pbio.0050199

BIOGAS

Biogas Composition

- CH_4: 50–75%
- CO_2: 25–50%
- N_2: 0–10%
- H_2, H_2S, and O_2: trace

Energy

- 20 MJ/m^3

BIODIGESTERS: DESIGN

Design specifications for vital microorganisms:

- Temp. 30 - 40°C (mesophilic)
- Anaerobic conditions (NO oxygen)
- pH 6.8 – 7.5
  - Regular feeding with appropriate feedstock (C:N)
- Feedstock maceration

- Starting a biodigester:
  - 50% manure & 50% water
  - Use manure only, not vegetative matter (no methanogens yet).
  - Cow manure is best. Others OK (including human). NO chicken (high ammonia).
  - When filling bag/vessel, be sure valve is open for safety release so any trapped air can escape.
  - Add inoculant.
- Common sources of problems
  - Leaks
  - Temperature
  - pH

BIODIGESTERS: CALCULATIONS

Estimating volume:

If we assume that the density of slurry is roughly the density of water ( ), then

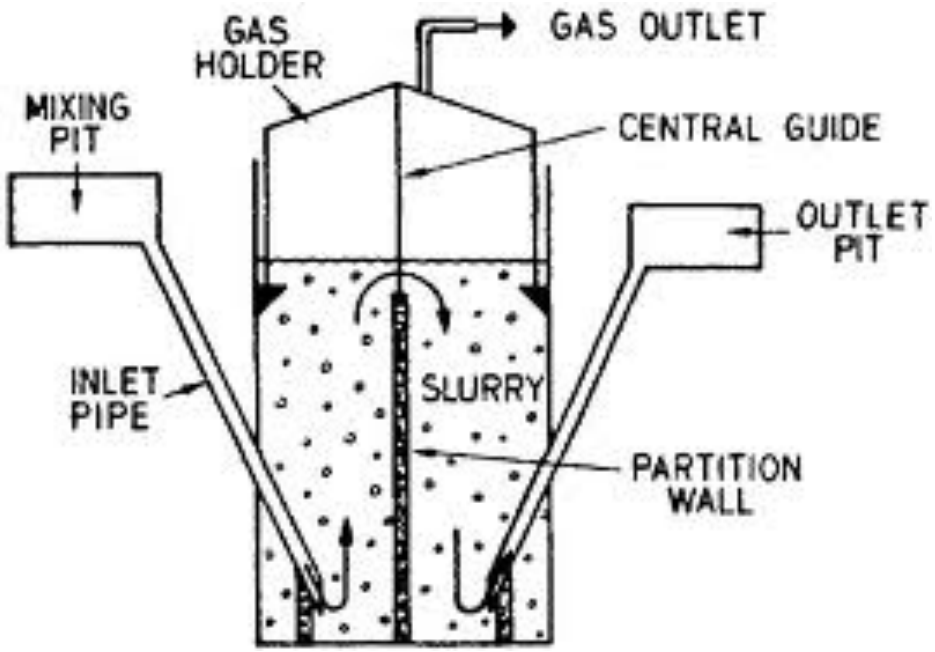
$$V_{biodigester} = \left(m_{\frac{waste}{month}} + m_{\frac{water}{month}}\right) \div \rho_{slurry}$$

$$1\frac{ton}{m^3}$$

$$= \frac{(10.9\ ton\ + 10.9\ ton)}{1\frac{ton}{m^3}}$$

$$\approx 22m^3;$$

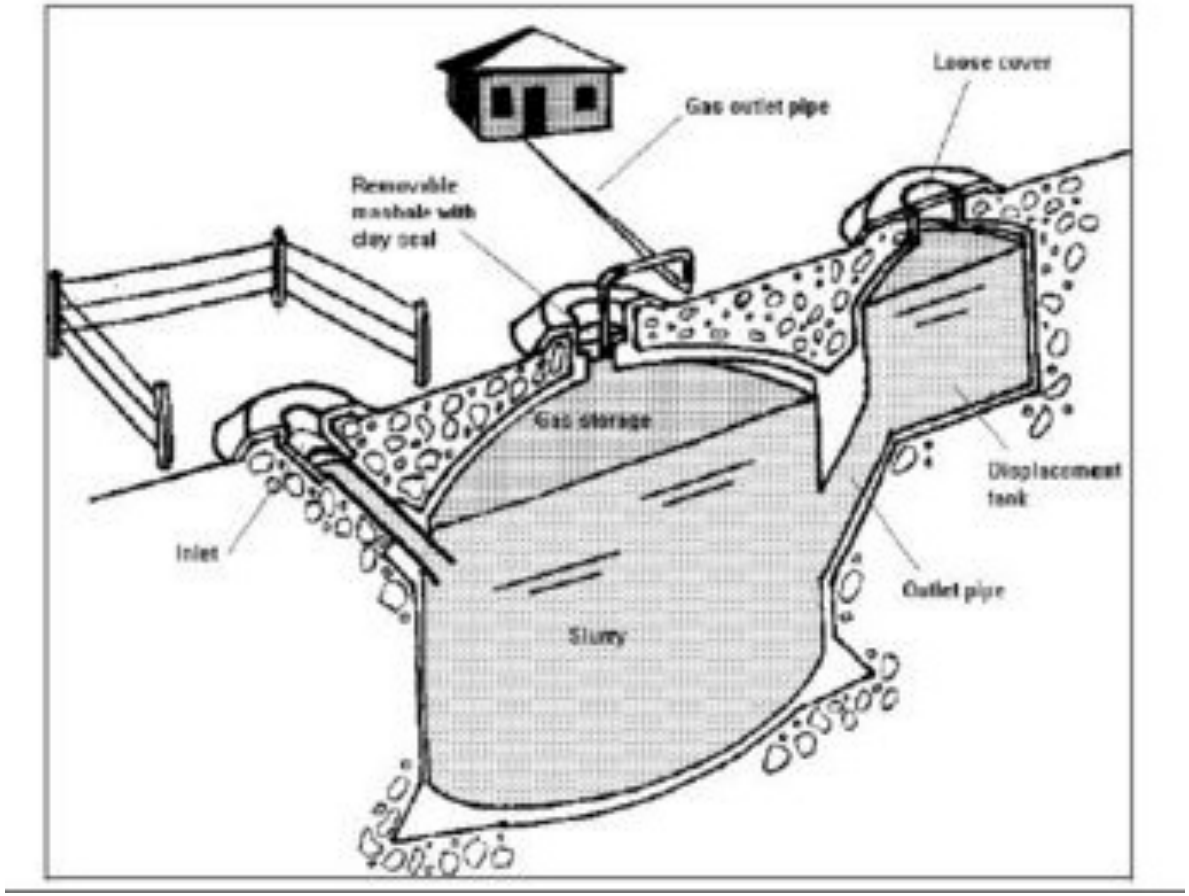
BIODIGESTER DESIGNS: FLOATING DOME



BIODIGESTER DESIGNS: FIXED DOME

Fixed dome (usually concrete)

- Most expensive
- If done correctly, lasts for a long time
- Hard to build correctly
  - Can't fix without breaking whole thing apart
  - Hard to get airtight – solutions: bag, coating
- No good way to know how much biogas is being produced

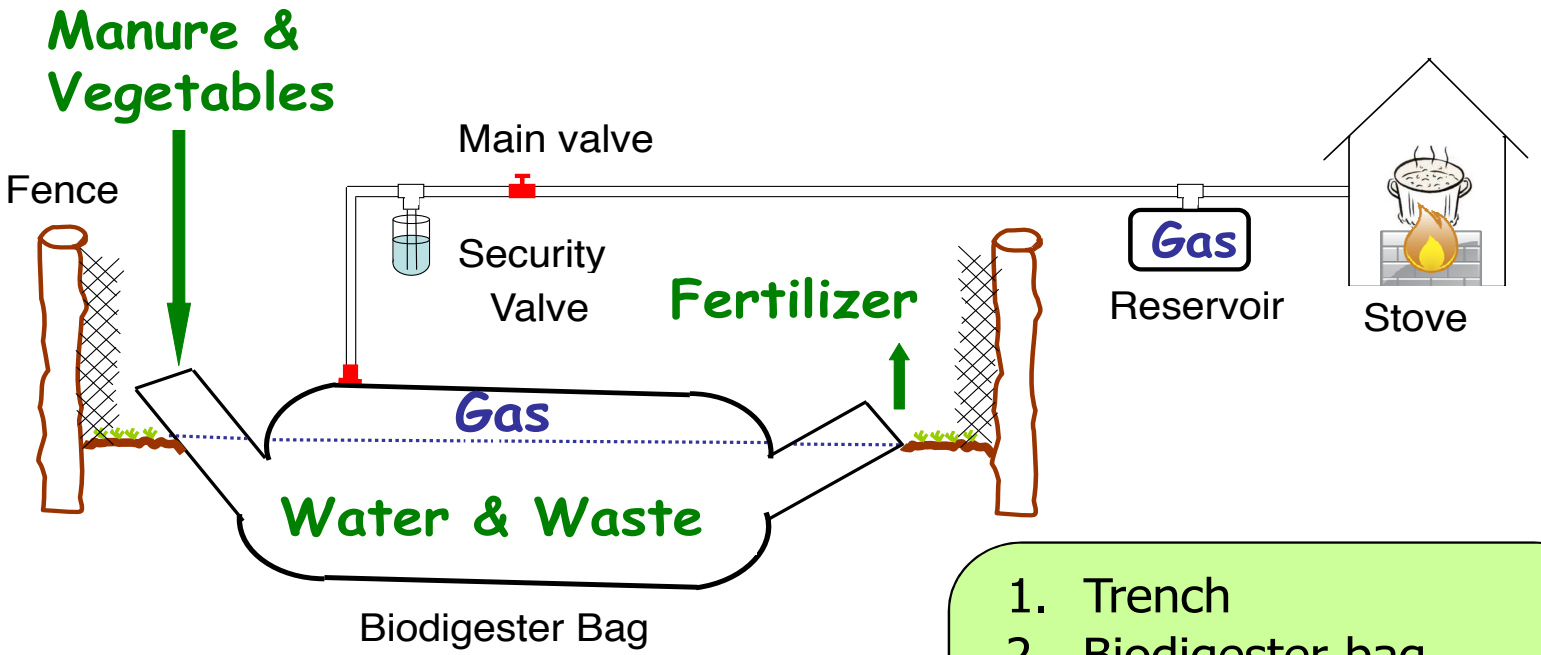


BAG BIODIGESTER

This design is based on a plastic bag, which offers the following benefits:

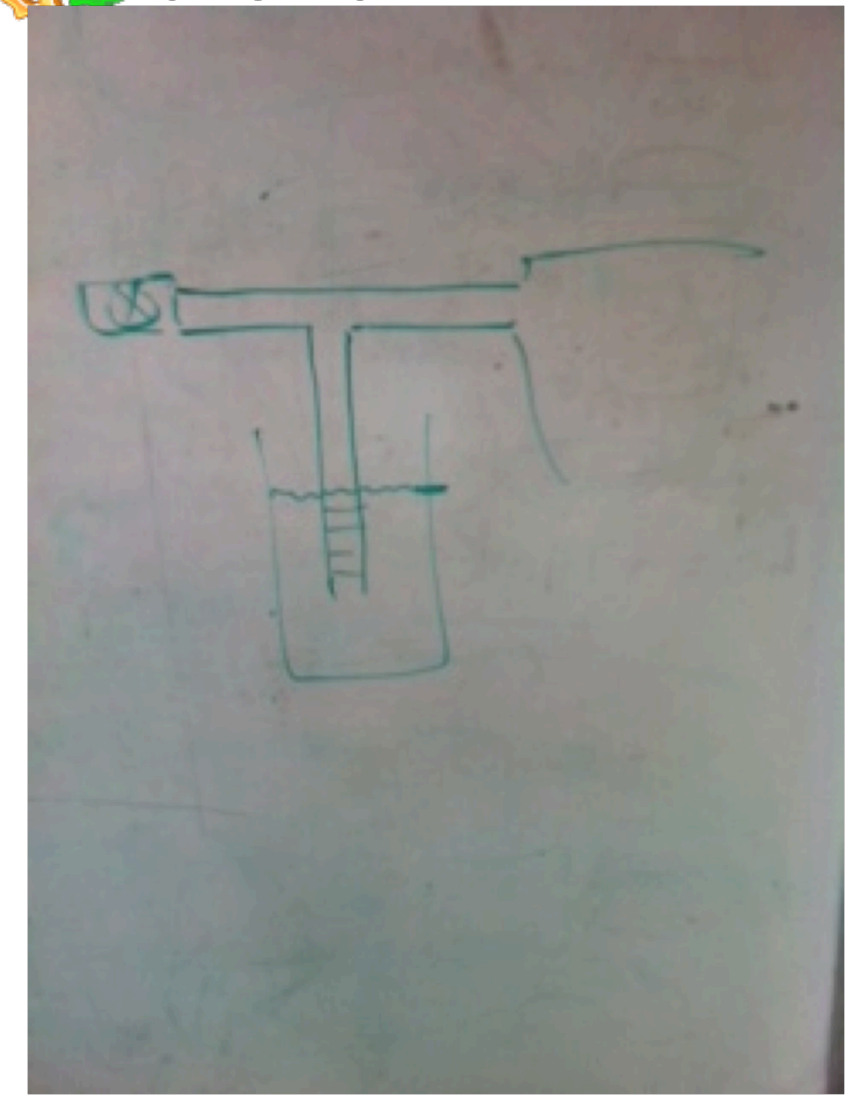
- Cheap
- Easier to build
- Lasts for about 7 years
- UV degradation shortens lifespan
- Puncture risk

BIODIGESTER PARTS

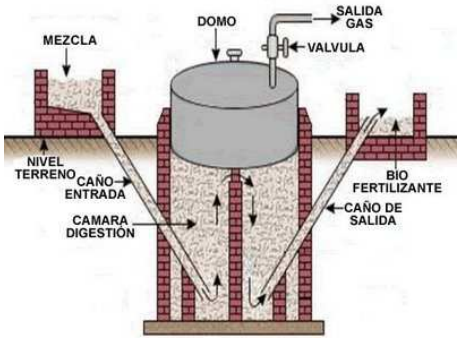


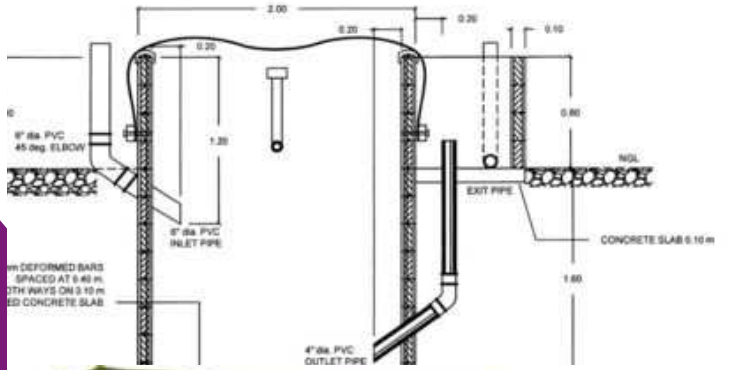
1. Trench
2. Biodigester bag
3. Gas line
4. Inlet and Outlet
5. Security valve
6. Gas reservoir

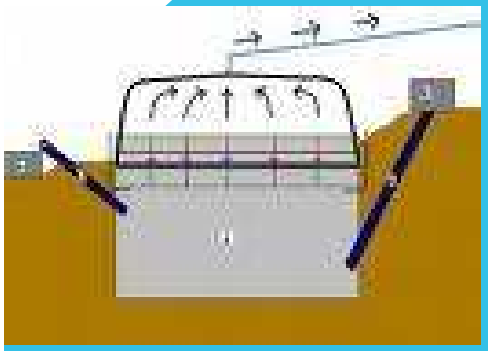
CAUTION: MAINTAIN WATER LEVEL!

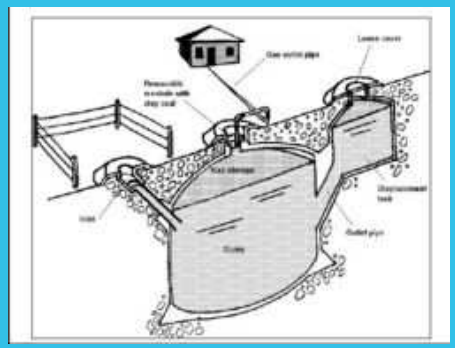


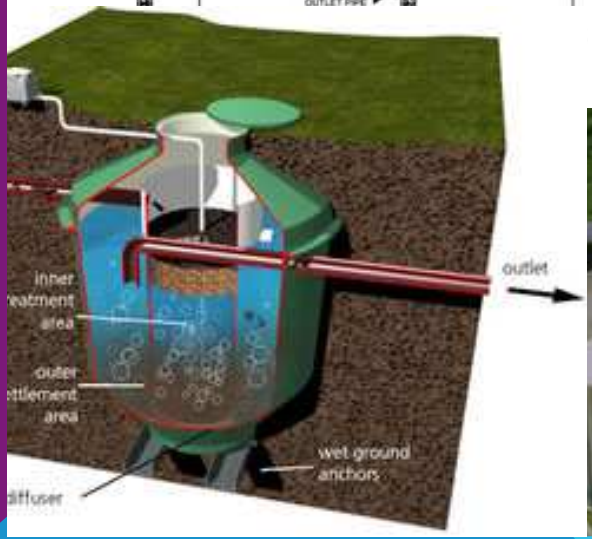
Biodigesters











BIOFUELS

Biofuels are fuels made from non-petroleum products.

We will talk briefly about biodiesel today.

- What do you know about biodiesel?

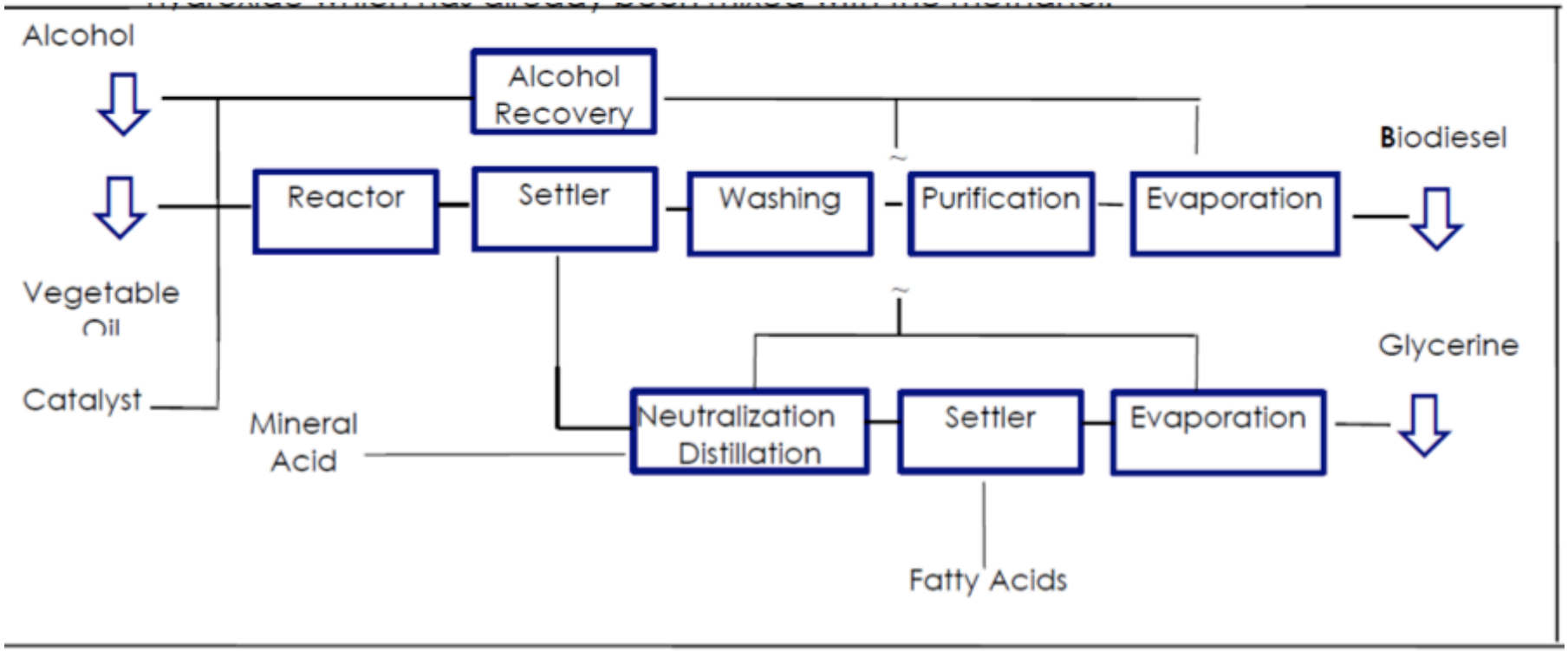
BIODIESEL

Biodiesel is any alkyl ester that is made from raw vegetable oil.

The oil is subjected to processes called transesterification or esterification.

- In a nutshell: oil + alcohol ⟶ alkyl ester + glycerin

BIODIESEL


Alcohol
Alcohol Recovery
Biodiesel
Reactor
Settler
Washing
Purification
Evaporation
Vegetable Oil
Glycerine
Catalyst
Mineral Acid
Neutralization Distillation
Settler
Evaporation
Fatty Acids

USING BIODIESEL

- Biodiesel has been widely approved/standardized. It performs no worse than petrodiesel in cold temperatures.
- It can be blended with petrodiesel or used on its own in diesel engines.
- It *may* degrade rubber lines faster.
- Advantages of using biodiesel:
  - Reduction in unburned hydrocarbons, CO, particulates.
  - NO CO_2, sulfur oxides, or sulfates!
  - NOx reduction depends on modifications made to the car.

WHAT ABOUT STRAIGHT VEGETABLE OIL?

- You can put vegetable oil in your car without converting it to biodiesel, but it's not as effective.
  - Must make some conversions to engine/lines.
  - Flocculants and other crap floating around can damage the engine – must strain/clean.
  - The engine does not last as long.
  - The oil gels at a higher temperature, making it difficult to use in cold weather.

BIODIESEL FROM ALGAE?

- Burning algae as fuel does release CO_2, but the growth of more algae absorbs the same amount.
- Arguably harmless to environment
- Expensive

WATCH
https://www.youtube.com/watch?v=xrbXxyM8c-g

BIODIESEL AROUND THE WORLD

- Large-scale production efforts in Central and South America are most notable in:
  - Brazil
  - Argentina
  - Guatemala
  - Costa Rica
- In Nigeria, waste vegetable oil and jatropha oil are the most commonly used feedstock.

BIOFUEL: GOOD OR BAD?

Potential benefits

- Small-scale biofuel production is still very limited, but it could…
  - Reduce fuel prices in rural areas
  - Create a new local economy

Challenges

- Food prices
- Farming conditions
- Environmental degradation

MAKING THE BIOGAS DIGESTER

Limited version that demonstrates the concepts

- The bag
- Start of the piping system

Materials

- 2 clear polyethylene plastic bags (open on both ends), sized according to the fuel needs
- 122 cm (4 ft) wide tube. We will be sizing for 4hours of coooking time per day. S
- Tarpaulin large enough to completely wrap around the polyethylene bags and cover the entire length of the bags. 9ft by 12ft should do.
- Needle and thread
- 2 buckets (5 gal/~20 L, new or used)
- Used automobile or bicycle tire inner tubes
- 1 PVC male adapters (inner diameter (ID) around 19 mm = ¾ in)
- 1 PVC female adapter (19 mm = ¾ in ID)

Tools

- Hacksaw
- Pliers
- File
- Sandpaper
- Scissors
- Measuring tape

STEP 1

Make the washers
Cut out the bottom of both buckets.
Select one of the bottoms and drill four holes the size of the inside diameter of your PVC in it.
Make four round washers.

STEP 2

Make the inlet and outlet tubes

File down the edges of the buckets so they are smooth (the buckets are the inlet and outlet tubes).

STEP 3

Assemble the bags

Cut the bags to the right length:

Cut one stretches of plastic bag (each of length x=L+4 meters)

Cut the tarpaulin to the same length

Fold each tarp lengthwise and sew the edges together to make two open-ended bags.

Lay the tarp bags out on the flat, smooth area, and pull the doubled-up plastic bag through one tarp and then through the second. Now there should be a bag of two layers of material with two open ends. Note that you will normally need four layers of materials for a practical biodigester to reduce the risk of leakage and piercing by plant roots.

STEP 4

Choose a location for the methane exit hole. This might be somewhere around the mid-length of the pipe or someplace more convenient.

Make a hole through both layers of bag, without harming the plastic layers on the other side. One way to do this is by placing a piece of smooth wood inside the bag and then using a hole cutter to cut a hole through the top layers of plastic and into the wood in the middle (the wood protects the bottom layers of plastic from being cut).

Send someone inside the bag with the PVC male adaptor, a plastic washer, and a rubber washer. Again, it may be possible to do this without actually going inside the bag.

Attach the connection as below.

STEP 5

Put the buckets on the bag

Fold the end of the bag in a fan formation (paper fan style) and pull it through the assembly of three buckets, then around the sides.

Make sure the methane outlet is still at the top of the bag and in the location you would like it to be once you place in the bag in the trench.

Make sure there is a pathway for waste to travel through the buckets inside the innermost bag - you can use a blunt-ended stick to reach through the bags in these bucket-tubes. If you can feel the end of the stick below the bottom of the buckets, the path is sufficiently clear.

Fold the end of the plastic bags sticking out past the buckets over the edges of the bucket-tubes, and tie them down with some rubber tube. Make sure they are tied down securely.