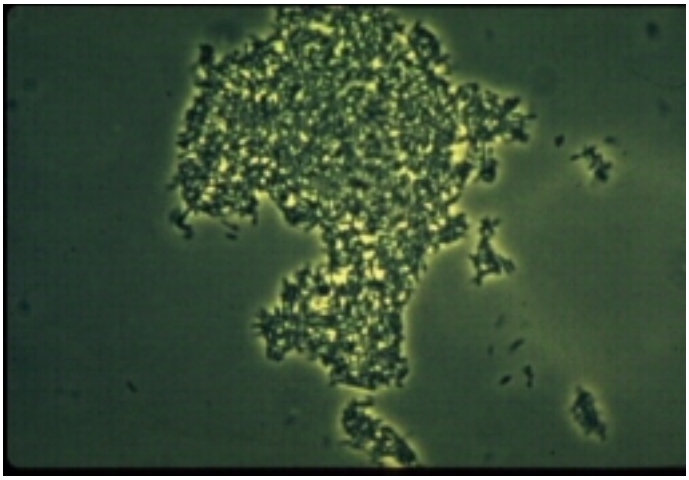
Basic Principles

What Is Biogas?

Biogas is actually a mixture of gases, usually carbon dioxide and methane. It is produced by a few kinds of microorganisms, usually when air or oxygen is absent. (The absence of oxygen is called “anaerobic conditions.”) Animals that eat a lot of plant material, particularly grazing animals such as cattle, produce large amounts of biogas. The biogas is produced not by the cow or elephant, but by billions of microorganisms living in its digestive system. Biogas also develops in bogs and at the bottom of lakes, where decaying organic matter builds up under wet and anaerobic conditions.



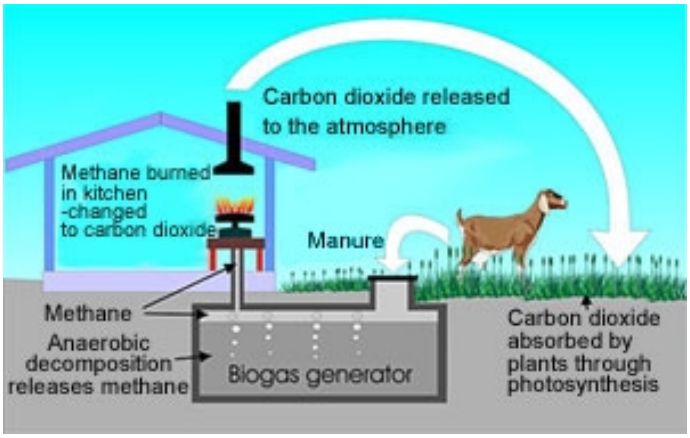
A microscope photo of the methane-producing bacteria.
Photo courtesy of University of Florida, Agricultural and Biological Engineering Department

Besides being able to live without oxygen, methane-producing microorganisms have another special feature: They are among the very few creatures that can digest cellulose, the main ingredient of plant fibres. Another special feature of these organisms is that they are very sensitive to conditions in their environment, such as temperature, acidity, the amount of water, etc.

Plant-eating animals such as bison release large amounts of biogas to the atmosphere.

Biogas is a Form of Renewable Energy

Flammable biogas can be collected using a simple tank, as shown here. Animal manure is stored in a closed tank where the gas accumulates. It makes an excellent fuel for cook stoves and furnaces, and can be used in place of regular natural gas, which is a fossil fuel.



Biogas is a form of renewable energy, because it is produced with the help of growing plants.

Biogas is considered to be a source of renewable energy. This is because the production of biogas depends on the supply of grass, which usually grows back each year. By comparison, the natural gas used in most of our homes is not considered a form of renewable energy. Natural gas formed from the fos

silized remains of plants and animals-a process that took millions of years. These resources do not "grow back" in a time scale that is meaningful for humans.

Biogas is Not New

People have been using biogas for over 200 years. In the days before electricity, biogas was drawn from the underground sewer pipes in London and burned in street lamps, which were known as "gaslights." In many parts of the world, biogas is used to heat and light homes, to cook, and even to fuel buses. It is collected from large-scale sources such as landfills and pig barns, and through small domestic or community systems in many villages.

For more information about biogas, read the backgrounder entitled Biomass Energy.

Build It!

The apparatus you are going to build uses a discarded 18 litre water container as the "digester." A mixture of water and animal manure will generate the methane, which you will collect in a plastic balloon. The 18 litre water container performs the same task as the stomach of a livestock animal by providing the warm, wet conditions favored by the bacteria that make the methane.

Safety Precautions

The main hazards in this activity are from sharp tools such as tubing cutters and scissors. Exercise caution while using any tool. There is no risk of explosion due to the leakage of methane because the gas develops so slowly that it dissipates long before it can reach flammable concentrations in room air. Exercise the normal precautions in the use of Bunsen burners: keep hair and clothing away from the burner while it is lit.

Tools

- Tubing cutter
- Scissors
- Adjustable wrench
- Rubber gloves
- Electric drill with ¼" bit, or cork borer
- Hot glue gun, with glue sticks
- Electrical or duct tape
- Sandpaper (metal file will also work)

Materials

- Used 18L clear plastic water bottle
- Large Mylar helium balloon

Plastic water bottle cap (with the "no-spill" insert-see photo)

- Copper tubing (40 cm long, 6.5mm (1/4") inside diameter)
- T-connector for plastic tubing (barbed, 6mm or ¼" long)
- 1 cork (tapered, 23mm long)
- Clear vinyl tubing (1.5 m long, 4mm or ¼-inch inside diameter)
- 2 barb fittings (¼" x ¼")
- Ball valve (1/4")
- 6-8L manure pellets (goat, sheep, llama, rabbit, or other ruminant)
- Rubber gloves
- Large plastic funnel (can be made from a 4L plastic milk jug with bottom removed)
- Wooden dowelling or stick (30 to 50 cm long, 2-3 cm thick)

The materials and tools you'll need to build a biogas generator.

Sources

Water bottle: Many hardware and grocery stores now sell purified water that they bottle on site. They often collect containers that can no longer be refilled because of dirt or damage to the bottle. These unrefillable bottles are frequently available for free. Ask to speak to the clerk in charge of refilling bottles. Ask for a used cap as well.

Mylar balloons: Check with any local florist or novelty store.

Tubing, valves, T-connectors, barb fittings: Check at your local hardware or plumbing supply store.

Manure: If you do not know someone who has domesticated rabbits, sheep, llamas or other similar pellet-producing animals, you can often purchase sheep or steer manure by the bag at your local garden center.

A. Prepare the biogas collection system

1. Cut a 20cm piece of copper tubing. Round off the sharp edges of the freshly cut tubing using sandpaper or a metal file.

2. The Mylar balloon has a sleeve-like valve that prevents helium from escaping once it is filled. This sleeve will help form a leak-proof seal around the rigid tubing. Push the tubing into the neck of the balloon, past the end of the sleeve, leaving about 2cm protruding from the neck of the balloon, as shown below.

Inserting copper tubing.

3. Test the tube to be sure air can enter and leave the balloon freely, by blowing a little in through the tube. The balloon should inflate with little or no resistance, and the air should be able to escape easily through the tube.

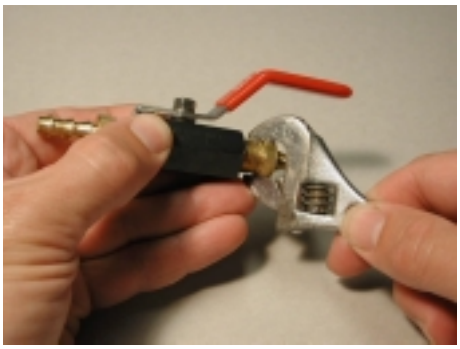
4. Securely tape the neck of the balloon to the tube as shown in the illustration.

Taping the neck.

5. Using a drill or cork borer, make a small (4mm) hole in the center of the stopper. Add a few drops of hot glue around and inside the hole and insert the stem of the ¼-inch T-adapter into the cork.

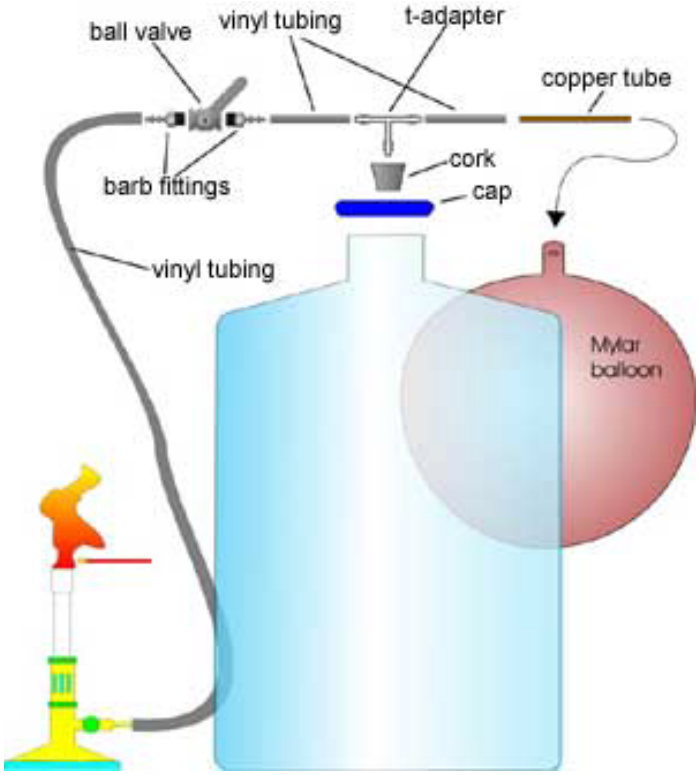
Gluing cork.

6. Screw the two barb fittings into the body of the ball valve. Tighten with the adjustable wrench.



Installing the barb fittings on the ball valve.

7. Cut two sections of vinyl tubing, each 25cm long. Use them to connect the balloon to the T-adapter, and to connect the ball valve to the Bunsen burner. Assemble the rest of the gas collection system according to the diagram below.



Assembly of the biogas collection system.

B. Prepare the manure mixture

This is a job best done outside, with rubber gloves!

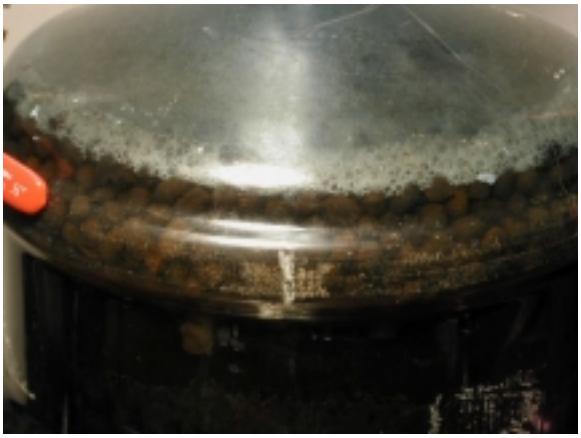
1. Cut the bottom off a 4L plastic milk jug to make a wide-mouthed funnel.

2. Place the funnel into the neck of the plastic water bottle and scoop in small amounts of manure.

Scooping manure.

3. Use a stick or piece of dowelling to push the manure through the neck of the bottle if it gets plugged.

4. Add enough water to bring the level close to the top of the water bottle.



Slurry level.

5. Use the stick to stir up the manure and water mixture, releasing any bubbles of air that might be trapped.

6. Clean up carefully. Use soap and wash hands thoroughly.

C. Final Set-up

1. Snap the cap onto the top of the manure-filled 18 litre water bottle.


Completed biogas generator.

2. Be sure the ball valve is closed, but that gas moving from the water bottle can pass freely through the T-adapter to the balloon.

3. Set the biogas generator in a warm location, such as over a heat register or radiator or in a sunlit window. If the biogas generator is placed in a window, be sure to wrap the outside of the container in black plastic or construction paper, to discourage algae from growing inside the bottle.

Test It!

For the first few weeks, your biogas generator will produce mainly carbon dioxide. When the aerobic bacteria use up all the oxygen inside the bottle, the anaerobic bacteria, which make methane, can take over. It can take up to a month for the generator to start making biogas with enough methane to be flammable.

When gas begins to accumulate in the balloon, test it by attempting to light the Bunsen burner:


Use caution when testing the biogas.

1. First, open the clamp or valve so that biogas can flow back from the balloon to the Bunsen burner.

2. Have a friend squeeze the Mylar balloon gently while you attempt to light the Bunsen burner with a match or spark igniter.

3. If your Bunsen burner ignites, your biogas generator is a success!

Questions

1. Why is biogas considered a source of renewable energy?

2. In what appliances or to what uses could biogas be applied?

3. What are some of the practical limitations to using biogas as an energy source on a large scale?

4. Where in Canada would biogas be a viable alternative to fossil fuels?

5. Why do you not want photosynthetic algae (see Part C, # 3) growing in your “digester”?

Contact us at: education@pembina.org

Biomass Energy

What is Bioenergy?

Bioenergy is energy stored in materials made with the help of living things. An everyday example of bioenergy is wood heat. Wood is produced by growing trees, and contains highly flammable substances. Wood heat is probably humanity's oldest energy source. Other sources of bioenergy include alcohol and biogas. Alcohol is a flammable liquid made by certain yeasts, and biogas is a flammable gas similar to natural gas, made by bacteria.

Wood is a source of renewable energy.

The difference between getting fuel from living things such as trees and getting it from something like coal or oil is that bioenergy is renewable. Although fossil fuels were formed by organisms that lived eons ago, it takes so long to replace fossil fuels (millions of years) that for practical purposes, they are considered non-renewable. Peat (a brown or black material found in bogs) is another resource that is not easily replaced, taking hundreds of thousands of years to renew itself. To be considered renewable, the resources must be replaceable within our lifespan. For example, the wood used in your campfire replaces itself as the forest grows. Coal on the other hand can be taken from the earth only once, and cannot be replaced. If a forest is managed properly, it will provide wood forever. It is the same with other forms of bioenergy, including biogas and alcohols.

Fibre Fuel

Most green plants have large amounts of a stiff material called cellulose. Cellulose is one of the main ingredients in wood, and is extracted for use in papermaking. Green plants manufacture cellulose from sugars, which they make during photosynthesis. Because cellulose is made from sugar, it contains a lot of stored chemical energy, energy that originally came from the sun. This chemical energy can be released as heat when wood is burned.

This generating station in Canada burns biomass fuel from nearby sawmills to produce energy.

Photo courtesy of EPCOR

Wood has been used as a fuel far longer than any fossil fuel. In some countries, wood is still the main fuel for heating and cooking. In places where wood is scarce, other forms of plant fibre are burned. Grass, peat, and even cow manure can be used as a fuel, but these materials make very smoky fires!

As long as these materials are allowed to grow back as soon as they are used, they are considered a source of renewable energy. However, if too much wood is harvested too rapidly or in a way that damages the soil or other parts of the ecosystem, severe environmental problems can result.

Ethanol and Methanol

Ethanol and methanol are alcohols and are highly flammable. They can be made from plant sugars or plant fibres. Alcohol is produced by feeding plant materials into large heated tanks called digesters. Inside the tanks, chemicals or yeasts are added to change the plant materials into alcohol. The alcohol is extracted, purified, and prepared for use as a fuel.

Both ethanol and methanol make excellent fuels for cars and trucks. In fact, ethanol is used in the engines of Formula 1 racing cars. It burns very cleanly, and delivers more power than gasoline. Many service stations now sell fuels that contain a blend of gasoline and an alcohol, usually ethanol.

Ethanol and methanol can be made from plant materials such as corn, at refineries like this one.
Photo courtesy of DOE/NREL

Methanol and ethanol

This bus uses ethanol instead of gasoline as a fuel.
Photo courtesy of DOE/NREL

can be deadly poisons, especially in the amounts used to make transportation fuels. Methanol is especially toxic. Even small amounts breathed in as fumes or accidentally swallowed can cause blindness, severe liver damage, and death.

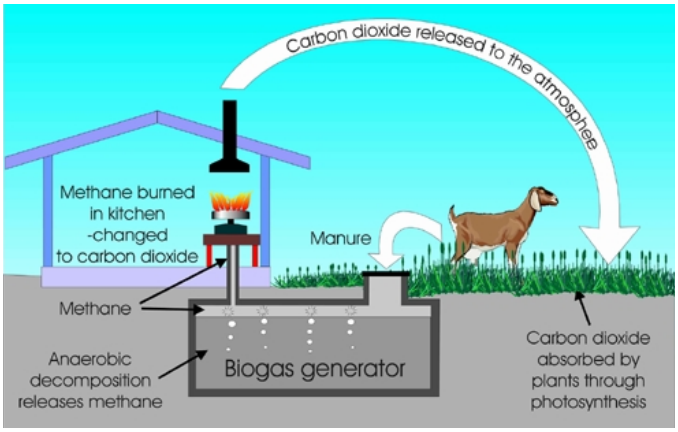
Biogas

Most mammals-humans included-produce a flammable gas called "biogas" as they digest their food. Bacteria living in their digestive systems produce methane as they break down cellulose present in the food. Biogas is also produced in bogs and wetlands where large amounts of rotting vegetation may accumulate. Biogas consists mostly of a gas called methane, which is the same as "natural gas", commonly burned in our furnaces and barbecues. Biogas can be used instead of natural gas for heating and cooking.

Two common sources of biogas. *Dave Mussell*

Humans have learned to duplicate this process in large tanks called biogas generators. To start the process, shredded plant materials and animal wastes are mixed with water in the biogas generator. Many kinds of naturally occurring bacteria arrive with the shredded plant material. The tank is then sealed so no air can get in. Within days, a special kind of bacteria in the tank will begin to produce biogas. These bacteria are known as "methanogenic", because they produce methane, the main ingredient in biogas. The biogas forms bubbles in the mixture, and collects at the top of the tank. It is piped to a large balloon-like bag where it is stored until needed.

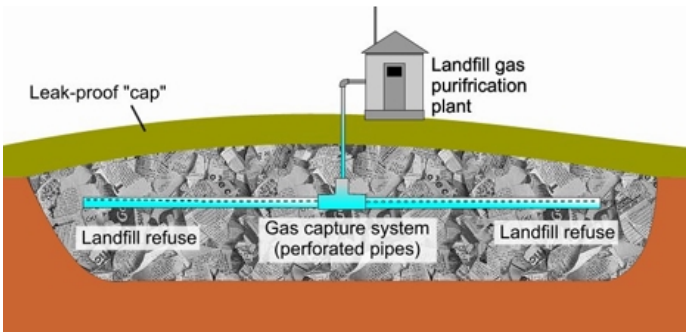
Eventually, the production of biogas in the generator starts to slow down. The mixture of water and manure is replaced with a fresh supply to start the process again. The old material is unable to produce



Biogas can be made using plant and animal wastes.

any more biogas, but still contains large amounts of plant material and other organic matter. It is dried to form a rich black soil, and is spread on fields as a fertilizer.

Another source of biogas is landfills. At the landfill site, large mounds of garbage are buried under the surface. Bacteria break some of the garbage down and can produce large amounts of biogas. This is sometimes collected and burned to heat buildings near the landfill. Biogas can contain traces of hydrogen sulphide (H2S) gas, particularly in the case of landfill gas. Care must be taken to deal safely with this gas because H2S can be fatal in small amounts.



Biogas can be captured from landfill waste.

Questions

1. Why is wood considered a form of renewable energy?

2. What are two kinds of bioenergy that can be used as fuels for cars and trucks?

3. Can you think of two environmental problems created by burning wood for heating and cooking?

4. What is the main ingredient in biogas?

5. Methane from landfills is often allowed to escape directly to the atmosphere. Can you think of two reasons why this is bad?

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Notes: