From Trash to Gas: Biomass Energy

Science Film Festival Knowledge Through Entertainment

Science Film Festival Film

Point of No Return

Introduction

It can be fun to take a drive through the beautiful countryside on a summer day, with the windows rolled down and your hair flying in the breeze. If you drive past a cattle farm though, you may be inclined to roll your windows back up! Although the smell of manure from cows and other ruminants can be strong and unpleasant, the waste is a rich source of energy that can be used to run the farm.

Manure is not the only waste that is a rich source of energy. What you might think is "just garbage," might actually be turned into energy. Dead plants, rotting food, wood chips, sawdust, leftover crops, nut shells, and paper products are all examples of biomass, which are natural materials or organic matter that can be used to make energy.

Is it hard to get energy out of biomass? No; in fact, people have been doing it for thousands of years. If you've ever sat around a campfire or fireplace, you've been warmed by burning biomass. Biomass can be burned on a larger scale to create electricity. Biomass (such as decaying plant matter, farm waste, wood waste, or industrial waste) is brought by large trucks to a huge incinerator where it is burned and the heat is used to boil water, create steam, and drive a steam generator that can produce electricity. Biomass energy is considered a form of renewable energy, meaning it can be replaced by nature. Biomass energy, along with other renewable sources, like hydroelectric, solar, geothermal, and wind energy, provide 7 percent of the total energy needs of the United States, and that percentage is expected to rise.

What other ways, besides burning, can you get energy out of biomass? You can turn it into a liquid or a gas. Turning it into a liquid involves a process called fermentation, which changes some forms of biomass—like corn, sugarcane, or switchgrass—into an alcohol-based fuel, called ethanol, which can power cars and be used as cooking fuel. Turning it into a gas is basically what cows do naturally in their digestive system, using bacteria to change biomass into methane, which is the main component in natural gas. Natural gas is an important fuel for heating homes; running stoves, ovens, and dryers; producing electricity and fertilizers; and running special cars and trucks. When made from biomass, natural gas is called biogas.

In aerobic sports—like running, walking, swimming, dancing, and bicycling—oxygen is used to generate the energy needed to continue the physical activity for a long period of time. For the creation of biogas, the opposite type of environment is needed to generate energy. Biogas is made by special anaerobic bacteria, microorganisms that live in environments without oxygen. The anaerobic bacteria break down the biomass into methane in a series of processes called anaerobic digestion. Biogas can be tapped directly from landfills,where sanitation workers dump and cover up everyone's trash, or from biogas generators where farmers or engineers mix biomass with anaerobic bacteria.

In this energy project, you will explore what kinds of biomass are good at making biogas. The kinds of biomass you will investigate are cow manure by itself and cow manure with vegetable peelings or with mashed banana. You will figure out how much biogas each biomass makes by filling empty soda bottles with these different types of biomass, sealing each bottle with a balloon, and measuring the inflation of the balloons (inflated mostly by methane!) over several days. Which biomass makes the most biogas?

Advanced

Resource Type

Project

Topics

Sustainability, Energy, Biomass, Renewable Energy, Natural Gas, Global Warming

Subjects

Engineering, Biochemistry

Keywords

Organic matter, Steam generator, Hydroelectric, Geothermal, Fermentation, Ethanol, Methane, Fertilizer, Biogas, Aerobic, Anaerobic bacteria, Microorganism, Carbon-neutral

Time For Activity

2 – 4 weeks

Safety Instructions

This project produces a small amount of a flammable gas, so it must be conducted in a well-ventilated area, away from any source of open flame or source of electrical sparks. Use caution and have an adult's help when using the bleach, as it can cause chemical burns.

From Trash to Gas: Biomass Energy

Key Objectives

- To be able to compare the amount of biogas that is produced from different types of biomass.

Materials

- Soda bottles, 1 liter, empty and clean (9)
- Masking tape
- Ruler
- Permanent marker
- Disposable gloves; available at drug stores and some hardware stores
- Small paper cups, 3 oz. (15)
- Kitchen scale or digital scale capable of distinguishing between 1 gram quantities.
- Fresh cow manure, enough to fill two sealable plastic sandwich bags, each bag measuring 6 1/2 inches by 5 7/8 inches (240 grams of manure total). Fresh cow manure may be available from farms and some petting zoos.

Tip: See step 3a of "Preparing Cow Manure Bottles" in the Tasks/Steps for how to make sure the cow manure is fresh enough.

- Optional: Plastic, disposable spoons
- Two types of biomass (60 grams of each):
  - Uncooked, chopped-up vegetable peelings (can be all one type of vegetable or mixed vegetables), such as from potatoes, carrots, and/or onions.
  - Mashed banana (takes about one banana)
- Funnel, should have an opening small enough to fit inside the mouth of the soda bottles
- Distilled water (9 L), available at grocery and drug stores
- Latex balloons, round, should be able to inflate up to 11 or 12 inches (9); available from Amazon.com
- Shipping tape, heavy duty, clear
- Bleach
- Tape measure, cloth or vinyl, metric
- Lab notebook
- Graph paper

Guiding Questions

1. **How can you get energy out of biomass?**
2. **How are vegetable peels and mashed bananas different from each other? How might these differences affect how these foods can be used to make biogas?**
3. **Does biomass energy impact global warming?**
4. **Is biomass energy a carbon-neutral source of energy?**
5. **What is special about the bacteria that make biogas?**

Tasks/Steps

Preparing the Soda Bottles for Filling

1. **Wash and dry the soda bottles. Recycle their caps.**
2. **With masking tape and a pen, label three of the bottles Cow Manure.**
3. **With masking tape and a pen, label three of the bottles Cow Manure + Vegetable Peelings.**
4. **With masking tape and a pen, label three of the bottles Cow Manure + Mashed Banana.**
5. **Using the permanent marker and ruler, make a small horizontal mark that is 2 centimeters (cm) from the top of each bottle. This is how full you will be filling each bottle. If you try to fill the bottles to the very top, it can be easy to overflow them.**
6. **Check nine balloons for any small holes that air might leak out of. If you find a balloon with a hole, replace it with one that does not have a hole.**
   - a. **You can check if a balloon has a hole by blowing a little air into it, holding the main hole shut, and listening for air escaping and watching for the balloon to slowly deflate.**

From Trash to Gas: Biomass Energy

Preparing Cow Manure Bottles

1. Put on a pair of disposable gloves.
2. Put one of the small paper cups on the balance scale and zero out the scale (or record the weight of the cup so you can subtract it from the final weight later).
3. Measure out 40 grams (g) of fresh cow manure in to the cup on the scale. You may want to use a disposable plastic spoon to help you scoop the manure. Carefully scoop the 40 g of cow manure (not the paper cup) in one of the soda bottles labeled Cow Manure. Throw the paper cup away.
   a. It is very important to use fresh cow manure in this project. Fresh manure is usually very moist, very soft, dark green/brown in coloring, and very smelly! Manure that is a few days old may still work, but for best results use manure that is as fresh as possible.
4. Repeat step 2 until all three bottles with this label have each been filled with 40 g of cow manure.

Preparing Cow Manure + Vegetable Peelings and Cow Manure + Mashed Banana Bottles

1. Using the balance scale and a fresh small paper cup, measure out 20 g of cow manure and carefully scoop the 20 g of cow manure (not the paper cup) inside one of the soda bottles labeled Cow Manure + Vegetable Peelings. Throw the paper cup away. Repeat this step until all three bottles with this label have 20 g of cow manure inside.
2. Using the balance scale and a fresh small paper cup, measure out 20 g of vegetable peelings, such as the peelings shown in Figure 2 below, and carefully place the 20 g of peelings inside one of the bottles labeled Cow Manure + Vegetable Peelings. Throw the paper cup away. Repeat this step until all three bottles with this label have 20 g of vegetable peelings inside.
3. Repeat steps 1-2 for the Cow Manure + Mashed Banana bottles, substituting mashed banana, for the vegetable peelings.
4. Take off your disposable gloves and throw them away. Wash your hands with soap and warm water, and dry them well. Put on a fresh pair of lab gloves.

Finishing the Bottles

1. Place the funnel in one of the soda bottles.
2. Carefully fill the bottle with distilled water to the mark you made 2 cm from the top of the bottle. Pour very slowly as you near the top so that the bottle does not overflow.
3. Cover the mouth of the filled soda bottle with a completely uninflated balloon.
   a. When you are putting the balloon on the mouth of the bottle it is very important that you hold the balloon so that it is completely uninflated. If there is air in the balloon, when you put it on the mouth of the bottle the air will remain trapped in the balloon and this can give you false results.
   b. As you put the balloon on the mouth of the bottle, aim the balloon so that its opening is right over the mouth of the bottle (and not off to the side, where its opening might be blocked by the side of the bottle's top).
   c. Be sure to only use a balloon that you have made sure has no small holes that air might leak out of.

From Trash to Gas: Biomass Energy

4. Secure the balloon at the mouth of the soda bottle with a couple strips of heavy duty, clear shipping tape. Make sure that the entire opening of the balloon is completely sealed around the mouth of the bottle.
   a. Do not adjust the shipping tape once you have put it on the balloon because this can rip the balloon.
5. Repeat steps 1-4 until all soda bottles have been filled and topped with balloons. When you are done, you should have bottles that look like the ones in Figure 4 below (except three bottles for each condition, not just one).
6. Take off your lab gloves and throw them away. Wash your hands with soap and warm water. Because you were working with waste, it is important to thoroughly clean the scale, funnel, and work area with a bleach solution.

Testing the Bottles

1. Place the soda bottles in a well-ventilated area, away from open flame or sparks of electricity, such as outdoors on a porch or balcony.
   a. If the bottles are in a relatively cold place, it may take longer for the balloons to inflate than if the bottles were placed in a warmer place.
2. Use the measuring tape to measure the circumference (in centimeters) of each balloon, at its fullest part. Record the date, time, and measurements in a data table in your lab notebook.
3. Each day, at approximately the same time, repeat step 2 for a total of 12 days.
   a. It may take up to about a week before you can visibly see some of the balloons inflating. If you think that the balloons are not inflating as they should, see the "Troubleshooting" section below.
4. When you measure the balloons, take a look at the bottles too. You may notice that in some bottles a large amount of biomass has floated to the top of the bottle, as shown in Figure 5 below. If this happens, you should make a note in your lab notebook and carefully tilt the bottle by about 45 degrees (so that it is momentarily horizontal) to dislodge the biomass. When you tilt the bottle, make sure that the balloon is securely on the mouth of the bottle and that no other leaks may allow liquid to escape.
   a. If enough biomass accumulates at the top of the bottle, it may prevent some biogas from getting into the balloon.
   b. If you need to tilt one bottle, you should tilt all of the other bottles. It is important that all of the bottles are treated the same way.
   c. You may notice a large amount of biomass floating at the top of some bottles every day during your experiment. Do not worry if this happens. Simply carefully tilt all of the bottles every time you see this, as described above.

Analyzing Your Data Table

1. For the bottles labeled Cow Manure, make a graph that plots the circumferences of the balloons on the y-axis (in centimeters) and the day number (1-12) on the x-axis. You can make the graph by hand or use a website like Create a Graph to make the graph on a computer and print it.
2. For the bottles labeled Cow Manure + Vegetable Peelings, make a graph that plots the circumferences of the balloons on the y-axis and the day number (1-12) on the x-axis.
3. For the bottles labeled Cow Manure + Mashed Banana, plot the circumferences of the balloons on the y-axis and the day number (1-12) on the x-axis.

From Trash to Gas: Biomass Energy

4. Comparing the three graphs, which type of biomass produced the fastest inflation of the balloons? Which type of biomass produced the greatest inflation of the balloons? Overall, which biomass do you think is the best at making biogas? What do you think it is about the best performing biomass that makes it so good at making biogas?

Troubleshooting

1. Do not worry if not all of your balloons become inflated. Not all bottles may produce enough biogas to inflate the balloons, but you should see the balloons become inflated by at least some of the bottles. If none of your balloons become inflated, here are some factors you can try changing for better results:

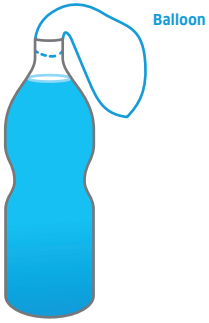
   a. Make sure you are using fresh manure. See step 3a in "Preparing Cow Manure Bottles" above for details.

   b. You could try increasing the amount of manure you use. If you do this, make sure you increase the amount by the same amount for every condition, and that you increase the amount of vegetable peels and mashed banana by the same amount as well.

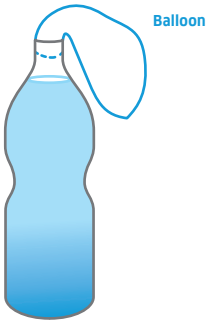
   c. Check to make sure that the balloons do not have any tiny holes and that they are tightly secured on the mouth of the bottle. You can do this by holding the balloon gently in one hand, and gently and slowly squeezing the bottle a little with your other hand. You should feel the balloon inflate a little.

2. If the three bottles for the same condition (for example, all the bottles with cow manure and mashed bananas) do not seem very consistent in how much biogas they are producing, this could be because different amounts of air were trapped in the balloons when they were placed on the bottles. See step 3a in "Finishing the Bottles" above for details.

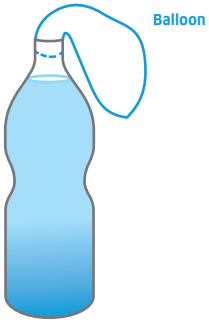
3. Some of the inflated balloons may deflate a little bit (by 2 cm or so) after about a week. Do not worry if this happens, as a tiny amount of biogas may escape from the inflated balloons over time. However, if an inflated balloon deflates a lot, this may be a sign of a leak in the balloon.



Bottle with Cow Manure



Bottle with Cow Manure + Vegetable Peels



Bottle with Cow Manure + Mashed Bananas

Authors/Source

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