# Clean Energy from Texas Landfills

RENEWABLE ENERGY
THE INFINITE POWER
OF TEXAS

## For High School

## OVERVIEW

In this unit, students will learn how chemical energy stored in plants can be converted to other forms of energy by burning a peanut and calculating the calories of heat produced. Students will locate Texas cities with landfills having potential for energy recovery. Students will reorder data, read from varied sources and form opinions on the use of landfill gases.

## OBJECTIVES

See High School Teacher Resource Guide for TEKS objectives and additional information regarding this and other high school units.

## SUGGESTED TIMEFRAME

Teacher will need to determine how many class periods to devote to each activity, based on the suggested timeframe and length of classes.

| Time | Activity Description | Content Area |
|---|---|---|
| *60 minutes* | **1** – Anticipatory Set, Introduction and Reading Passage | Science<br>Social Studies<br>Vocabulary<br>Reading |
| *90 minutes* | **2** – Lab Activity – Calculating the Calories in a Nut | Science<br>Mathematics |
| *45 minutes* | **3** – Assessment | Science<br>Vocabulary |
| *60 minutes over two class periods a week apart* | **4** – Follow Up Lab Activity – Making Landfill Gas/Making a Landfill | Science<br>Social Studies<br>Reading |

## REQUIRED EQUIPMENT

- ➤ copy of the Reading Passage and Student Data Sheets for each student
- ➤ equipment for teacher to make a calorimeter for each lab group
  - large coffee can (1 or 2 lb. size)
  - sheet metal cutting tools
  - can opener
  - gloves
  - safety glasses or goggles
  - tape (duct, heavy masking tape etc.)
- ➤ an equipment kit for the Lab Activity for each student group containing the following:
  - marker
  - large coffee can calorimeter
  - large Pyrex test tube
  - clay
  - 1 sewing needle (medium)
  - thermometer
  - small cork (cork, not rubber)
  - peanuts and/or other nuts (pecan, Brazil, walnut, macadamia)
  - water
  - goggles
  - gloves
  - graduated cylinder (10 or 25 ml)
  - electronic or other sensitive balance for determining the mass of each nut
- ➤ an equipment kit for Follow Up Lab "A" (Making Landfill Gas) for each student group containing the following:
  - one 500 mL flat-bottom flask
  - two 250 mL flat-bottom flasks
  - petroleum jelly
  - organic slurry (manure, grass clippings, kitchen waste, etc., mixed with water and processed in a blender until a thick, but pourable, consistency is reached))
  - sandwich bag (not the kind with a zipper top)
  - rubber band
  - three two-hole rubber stoppers
  - four 10-cm pieces of glass tubing, with fire polished ends
  - two 20-cm pieces of glass tubing, with fire polished ends
  - 1.5 m of clear aquarium tubing or equivalent
  - medicine dropper
  - clamp

- OR an equipment kit for Follow Up Lab "B" (Making a Landfill) for each student group containing the following:
  - one gallon milk jug
  - modeling clay (Kleen Klay® or equivalent)
  - organic compost
  - plastic bag
  - one foot of glass tubing
  - clear plastic wrap
  - scissors
  - rubber band

## BACKGROUND INFORMATION

Many cities collect municipal solid waste and dispose of it in landfills. There, the solid waste is compacted and covered with a layer of soil. The solid waste contains a substantial quantity of organic materials that can produce a variety of gaseous products as they decompose. The primary decomposer organisms under these conditions are anaerobic bacteria. These bacteria thrive in the oxygen-free environment of the landfill. The products of anaerobic decomposition of organic materials include such gases as sulfur dioxide and hydrogen sulfide (responsible for that "rotten-egg" smell), carbon dioxide, and methane. Methane is sometimes known as "swamp gas" because similar conditions can exist under the water in stagnant swamps. Methane is also the primary component of natural gas. The carbon dioxide generally dissolves into the ground water. Since methane is not soluble in water and is less dense than air, it collects and migrates out of the landfill. Landfill gas facilities collect this methane and burn it for energy.

Landfill gas is not synonymous with natural gas or methane. The terms should not be used interchangeably. The term "landfill methane" is also misleading and should not be used because landfill gas is not simply methane. Natural gas is a mixture of 80 to 99% methane, along with other hydrocarbons such as ethane, propane, and butane. Landfill gas contains approximately 50% methane along with nitrogen, oxygen, water, carbon dioxide, sulfur and various contaminants.

In the Lab Activity, students will create a calorimeter and measure the energy in a nut. A calorimeter measures the amount of energy released from an organic sample (food) in the form of heat. The food is placed in a combustion chamber and ignited by sparks. A larger insulated chamber, filled with water, surrounds the combustion chamber. After the organic molecules are ignited, the water in the calorimeter rises in temperature, so the mass of the water and the temperature change are used to calculate the calories in the food sample.

Students are asked to differentiate between direct and indirect use of biomass.  A direct use of biomass involves burning biomass directly, such as burning the nut in the activity.  An indirect use of biomass is allowing biomass to decompose and burning the methane gas collected from the decomposed materials. If the nut(s) were decomposed and the methane produced was burned instead of the nut itself, it would be indirect use of biomass. The indirect use has a bonus of decomposed compost available for use.

## SUMMARY OF ACTIVITIES

### Activity 1 – Anticipatory Set, Introduction and Reading Passage

Teachers should read the entire sequence of activities first, before starting the lab. As an anticipatory set, the teacher may elect to provide a dramatic attention-getter for the class by igniting methane gas as per Follow Up Lab Activity "A." The experiment would have to be set up at least one week in advance to produce landfill gas. Explain to the class the topic that will be covered in this unit of study. Teachers can include statements from the teacher background information section. Discuss the concept of a calorimeter and the terms "biomass," "direct use of biomass," and "indirect use of biomass."

Have students consider the following quote:

"The packaging for a microwavable 'microwave' dinner is programmed for a shelf life of maybe six months, a cook time of two minutes and a landfill dead-time of centuries." *David Wann*

Ask students if they are actually aware of how much a ton of trash is.

Each student will need a copy of the Reading Passage and the Student Data Sheets (includes reading comprehension questions and vocabulary words). Before starting the Lab Activity, instruct students to study the Reading Passage, "Clean Energy from Texas Landfills," and complete the Student Data Sheet. This activity will help them learn about landfill gases and some applications and limitations. Key vocabulary words in the Reading Passage will assist them in understanding the Lab Activity instructions. For students who wish to learn more about landfills, clean energy, bio-energy, or other forms of renewable energy, direct them to the appropriate resources. Suggested resources are included in the Teacher Resource Guide. The Reading Passage includes a table that lists landfills in Texas and their potential for energy recovery in terms of gas volume (million cubic feet) and electric potential (megawatts). The megawatt is included because it is a common unit that is used to compare equivalent electric potential of power generators that use difference sources of fuel (such as gallons of petroleum or cubic feet of gas). Appropriate safety guidelines should be reviewed, with cautions to students concerning careful handling of thermometers (non-mercury).

### Activity 2 – Lab Activity – Calculating the Calories in a Nut

#### Advanced teacher preparation:

This activity requires a "calorimeter" made from a coffee can for each group. This calorimeter should be prepared ahead of time, either by the teacher or assigned to a group of student aides.

Construction of calorimeter (see drawing in Lab Activity):

1. Remove the top of the coffee can with a can opener.
2. Using the metal cutters, cut out a pie shaped piece along the side of the top, about 2.5 to 3 cm high or high enough to insert the cork with needle (see diagram).

3. Turn the can over to the closed side (bottom side up).
4. Use the metal cutters to cut a round hole in the bottom of the can. (Or have the school shop punch holes in the bottom. Do not try to drill a hole. Drilling thin sheet metal is difficult and dangerous.)
5. Tape around the hole and around all of the exposed edges so that students will not cut their fingers.

1. The teacher should decide if each group will test just one peanut, just one kind of nut with several different sizes, or several varieties of nuts. If various kinds of nuts are distributed and assigned among different groups, less time will be required. Students must clearly understand what kind and how many nuts they will test. Each nut used can be weighed, using a balance (electronic), so that a measurement for both mass and increase in water temperature is taken. Oily nuts, such as Brazil nuts, macadamia nuts, pecans, and walnuts, should burn better. (This activity can also be done without determining the mass of the nuts.)

2. Explain to the class that during this activity, students will measure the energy available through combustion of a plant product, a peanut or other nut. Before beginning the activity, you may wish to demonstrate that a single peanut has sufficient energy to boil a small amount of water. If peanuts cannot be used in the classroom (because of peanut allergies), cheese puff snacks such as Cheetos® or other similar snacks can be substituted. Both peanuts and cheese puffs are loaded with vegetable oil and will burn fiercely. Emphasize to the class all safety precautions to be followed when dealing with open flames and hot water.

3. Distribute copies of the Lab Activity to each student but have students work in small groups as determined by the teacher. Before beginning the lab, students should review the instructions so they will understand the purpose and the goals. To enhance the class' scientific inquiry in this lab, instruct each student to develop statements for the following: hypothesis, predictions, conclusions and finally significance/implications. Note that the hypothesis and predictions should be made before beginning the Lab Activity. Refer to the Teacher Resource Guide for more information. Students can briefly outline the steps of the activity. To ensure that all students participate, instruct the groups to assign who will be responsible for each step in the activity before beginning. Ask students to obtain a materials kit. Students should record their temperature measurements on the Data Table provided in the Lab Activity. After students have completed their Data Tables, students should complete the data analysis questions listed in the Lab Activity.

4. Students can share information for the number of calories of the various kinds of nuts provided, as well as the mass of each nut (just the calories alone can also be used). A bar graph can be drawn either:
   a) for the one sample of one kind of nut;
   b) for the 3 or 4 kinds of nuts that one group used, or;
   c) for a class average format (for each kind of nut) both for mass and for the number of calories produced (or for calories alone).

A line graph can be plotted for the mass of individual nuts on one axis versus the number of calories produced to see if a pattern or relationship emerges. The percentage of oil in various types of nuts is another variable.

### Recommendations and Expected Observations

All of the nuts (or cheese puffs) should raise the temperature of the water substantially. Oilier nuts should produce more heat.

If the class data is compiled for graphing, the more oily nuts will probably have produced more calories, as they will burn more completely. If a calculation was made for how many calories were produced by 0.5 gms of each kind of nut, students could infer which kinds of nuts were most flammable or oily.

The usefulness of biomass (organic waste materials, which the nut represents) to produce energy has numerous benefits. Students can discuss clean burning of methane from landfill waste, with no cost for biomass. Locating the candidate landfills from the Table in the Reading Passage on a Texas map can give students an idea of the locations of potential landfill gas sources throughout the state.

### Activity 3 – Assessment

Distribute a copy of the Assessment Questions to each student. Instruct each student to work alone and answer the short answer and multiple choice questions. Collect the handouts, grade and return them to the students.

### Activity 4 – Follow Up Lab "A" – Making Landfill Gas

The teacher should determine which Follow Up Lab best suits the class. Follow Up Lab A can be used to model what happens in a landfill. If the digester can be kept warm (not hot, just warm), then some gas can probably be produced in a week or two. You may wish to have several sets of apparatus to test different organic slurry. Since inserting glass tubing into rubber stoppers can be tricky, you may wish to do this beforehand.

### Activity 5 – Follow Up Lab "B" – Making a Landfill

If you prefer, the alternative landfill activity can be done where the gas is produced, but not ignited.

## ADDITIONAL ACTIVITY

### Internet or library research

1. Students can learn about the uses of landfill gas systems in other countries. Canada has an active biomass energy program that uses some municipal waste. Refer to the Teacher Resource Guide for suggested resources.
2. Students can research how a calorimeter is used in a research laboratory. Chemistry texts, the Internet, and science journals can be used.

# Clean Energy From Texas Landfills

RENEWABLE ENERGY
THE INFINITE POWER OF TEXAS

## HIGHLIGHTS

- **Capturing landfill gas turns a potential nuisance into high value products**
- **Landfill gas is cheap and reliable**
- **Several Texas landfills are already capturing and using landfill gas to generate additional revenue**
- **Landfill gas is a small yet valuable resource available in many Texas communities**

## SUMMARY

Landfill gas (LFG) recovery may be the ultimate in recycling. It taps one of society's least desirable items, garbage, and turns it into useful, high value energy products such as electricity and natural gas. Turning hazardous LFG into marketable energy enhances landfill safety. It also reduces odors and greenhouse gases while generating revenue. Every large Texas city should carefully evaluate its LFG potential. Why? Because what used to be known as "the dump" has become one of America's most cost-effective and reliable energy resources.

## WHAT IS LANDFILL GAS?

Each Texan discards about a ton of trash per year. Consider that the average weight of an automobile is 3,500 pounds and that there are 2,000 pounds in a ton. That means that each year, every two Texans throw away more trash than a car weighs! Even with our best recycling efforts, most of the discarded trash is still buried

SOURCE: US DEPARTMENT OF ENERGY

**LANDFILL GAS INTO ELECTRICITY** *This small power plant located at a landfill produces low cost, reliable electricity.*

in municipal solid waste landfills, which are basically big piles of trash that are covered with dirt. Most trash is biomass, meaning it is derived from plants or animals. Examples of landfilled biomass include: food scraps, tree trimmings, dirty diapers, old newspapers, and discarded lumber.

When buried in the landfill, these materials break down and emit a mixture of methane and carbon dioxide along with a few other trace gases. The decomposition process will produce LFG for 30 years or more. Methane, which typically makes up half of all the gases emitted by a landfill, is the main component of natural gas and a valuable energy product. Therefore, LFG is considered a renewable form of natural gas. Although methane is a marketable commodity, methane is also a destructive “greenhouse gas” and landfill operators are required by federal law to control it. Twenty times more destructive to the Earth’s atmosphere than carbon dioxide, methane currently accounts for about 12 percent of America’s total greenhouse gas emissions.

Landfill operators are required to trap the methane and other gases. If the landfill volume is over one million tons, the methane produced can be captured, purified, and sold to gas utility supplies or used to generate electricity on the spot. Since the methane must be captured anyway, turning it into a commercial product can help defray the landfill’s operating costs while reducing pollution.

## TYPES OF PROJECTS

The simplest method of collecting and disposing of LFG is through the use of a flare. This technique was common 50 years ago for disposing of the explosive casing head gas that came along with the black gold from oil wells. But the oil industry eventually developed markets and infrastructure to sell the valuable natural gas rather than wasting it. In similar fashion, landfill operators are developing markets for LFG, which can be used for many applications.

Some of the applications for LFG are:

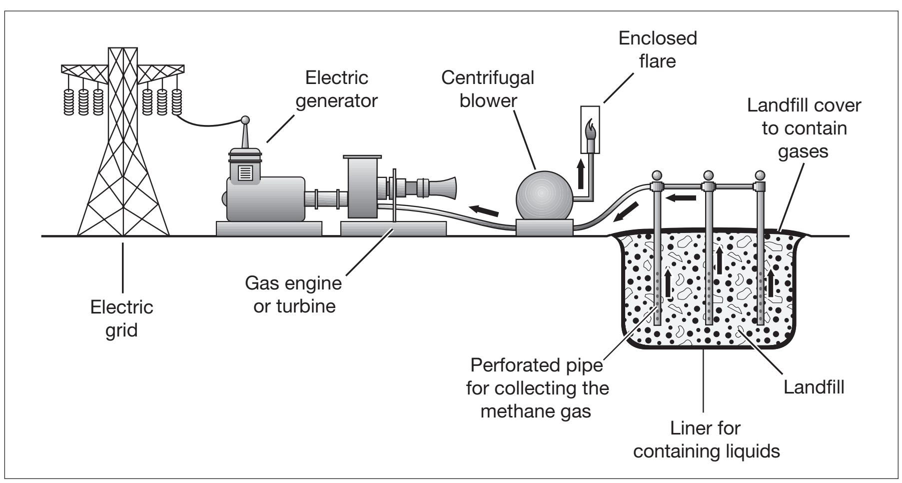
**HEATING** – burning gas for direct heating of homes and industry.

**PIPELINE GAS** – collected gases can be compressed, cleaned and separated into higher value products. LFG-derived methane can be sold as natural gas and transported to markets around Texas or in other states via natural gas pipelines.

**ELECTRIC POWER GENERATION** – LFG can fuel an internal combustion engine (e.g. truck engine) or small combustion turbine (e.g. jet engine) connected to a generator to produce electricity.

## TEXAS POTENTIAL

About 22 million tons of trash are landfilled in Texas each year. That trash, in turn, creates approximately 70 billion cubic feet of methane. That quantity is equivalent to 1 percent of the natural gas produced in Texas each year and




**SCHEMATIC DIAGRAM OF LFG-TO-ELECTRICITY PLANT** *Major components include the collection system, engine and generator.*

equivalent to seven percent of the gas used by Texas' electric utility companies.

If the 70 largest landfills in Texas were fully developed for energy use, approximately 40 billion cubic feet of methane now drifting into the atmosphere or being wasted in flares would be utilized. It is estimated that nearly 200 megawatts (MW) of electricity could be generated from this LFG, providing the electric needs of more than 100,000 Texas homes.

Nationwide, more than 339 LFG utilization projects are in operation and perhaps 600 additional projects are feasible. In Texas, 11 LFG-to-energy projects were in service by the end of 2002. At least 55 more projects are possible.

## AUSTIN'S LFG -TO-ELECTRICITY PLANT

Since 1996, Browning-Ferris Industries has been generating electricity from LFG at its Sunset Farms Landfill in Austin. This installation uses three 1,500 horsepower engines that are fueled by the methane-carbon dioxide mixture coming from the landfill. These engines, which are similar to large diesel engines, have relatively high initial costs – about $1,200 per kilowatt or about three times the cost per kilowatt of a large, natural gas-fueled power plant. But because they operate nearly continuously and use free, on-site fuel, they produce electricity at rates comparable to the cheapest conventional power plants.

Landfill gas powered units are highly reliable, producing full power for 90 to 95 percent of the year – a level higher even than fossil fuel and nuclear power plants. And due to their small size, LFG projects such as the one at Sunset Farms create "distributed" electricity, meaning that they connect directly into the local power grid, in contrast to giant conventional power plants that require high-voltage transmission lines with large metal towers to deliver power to customers.

**CANDIDATE LANDFILLS FOR ENERGY RECOVERY**

| City | Gas Volume in million cubic feet (mmcf/d) | Electric Potential megawatts (MW) |
|---|---|---|
| Abilene | 1.5 | 2.4 |
| Altar | 1.5 | 2.4 |
| Alvarado | 1.6 | 2.6 |
| Arlington | 1.7 | 2.8 |
| Austin – A | 1.8 | 2.8 |
| Austin – B | 1.4 | 2.2 |
| Avalon | 2.5 | 4.0 |
| Beaumont | 1.2 | 2.0 |
| Clint | 1.8 | 2.9 |
| Columbus | 4.4 | 7.1 |
| Conroe – A | 1.5 | 2.4 |
| Conroe – B | 2.0 | 3.2 |
| Corpus Christi | 1.3 | 2.1 |
| Creedmore | 2.5 | 4.0 |
| El Paso | 1.7 | 2.7 |
| Farmers Branch | 2.2 | 3.6 |
| Ferris | 2.3 | 3.6 |
| Ft. Worth – A | 1.5 | 2.3 |
| Ft. Worth – B | 1.6 | 2.6 |
| Houston | 5.4 | 8.7 |
| Laredo | 1.2 | 1.9 |
| Longview | 1.5 | 2.4 |
| McKinney | 1.3 | 2.0 |
| Plano | 2.9 | 4.7 |
| Rosenberg | 1.4 | 2.3 |
| Sinton | 1.6 | 2.6 |
| Tyler | 1.2 | 1.9 |
| TOTAL | 52.5 | 84.2 |

**TABLE 1. CANDIDATE LANDFILLS FOR ENERGY RECOVERY** *This list, compiled by the U.S. Environmental Protection Agency, identifies 27 of the more promising landfill sites in Texas. Additional sites in Texas may also be feasible.*

## Understanding the Reading Passage

Based on the information from the Reading Passage, answer the following questions:

1. As of 2000, there were 656,562 people living in Austin, Texas. How many tons of trash are generated each year by the residents of Austin? ______________________

   How many tons of trash are generated each year by your community? ______________________

2. Municipal waste contains at least 60% organic waste (household waste, paper, wood, box board, and other waste). How many tons of organic waste are available for landfill gas production in Austin, Texas?

   ______________________________________________

   How many tons of organic waste are available for landfill gas production in your community? __________

3. How can burning landfill gas for energy affect greenhouse gas emissions?

   ______________________________________________

   ______________________________________________

4. List 3 purposes for how landfill gas can be safely used:

   1 ______________________________________

   2 ______________________________________

   3 ______________________________________

## Vocabulary

Based on the Reading Passage, write down your understanding of these words or word pairs and verify your definitions in a dictionary, on the Internet if available or with your teacher:

biomass ______________________________

calorie ______________________________

chemical energy ______________________________

decompose ______________________________

direct use of biomass ______________________________

generator ______________________________

greenhouse gas ______________________________

indirect use of biomass ______________________________

landfill ______________________________

LFG ______________________________

methane ______________________________

natural gas ______________________________

perforated pipe ______________________________

potential energy ______________________________

## Lab Activity – Calculating the Calories in a Nut

### Introduction

The purpose of this activity is to demonstrate that chemical energy is stored in plants and can be converted to other forms of energy by burning a peanut and calculating the calories of heat produced.

### Before You Start

Review the vocabulary words from the Reading Passage. Ask your teacher if you are unsure of any of the meanings. Divide up all the steps in the Lab Activity first, so that everyone has a clear job to do.

### Materials

Obtain an equipment kit from your teacher. Check that it contains the following materials:

- marker
- large coffee can calorimeter
- large Pyrex test tube
- clay
- 1 sewing needle (medium)
- thermometer
- small cork
- peanuts and/or other nuts (pecan, Brazil, walnut, macadamia)
- water
- goggles
- gloves
- graduated cylinder (10 or 25 ml)
- sensitive balance

### Performing the Experiment

(wear goggles, use gloves)

1. Carefully insert the eye of the needle into the small cork and place this under the can in the middle. This will become the nut holder.
2. Holding the test tube, insert it into the hole in the top of the coffee can. When the bottom of the tube is about 2 cm above the needle in the cork, mark the tube with a line.
3. Wrap clay around and above the line on the test tube, so that the clay holds the test tube upright and securely in the hole. In fixing the test tube, the clay should adhere to the test tube to hold it firmly. A large rubber band could reinforce the clay, if needed.
4. Measure 10 ml of water in the graduated cylinder and pour it into the large test tube.
5. Remove the cork and needle from under the calorimeter.
6. Obtain a peanut or other nut and find its mass, using a balance, and record the mass in grams.
7. Carefully place the nut on the pointed end of the needle.
8. Place the thermometer into the test tube and record the initial temperature of the water on the Data Table. Use care in handling the thermometer.
9. As directed by your teacher, you or the teacher will light the nut with a match or lighter.
10. As soon as the nut has caught fire, carefully slide the cork, needle and nut under the test tube in the calorimeter, so the water in the test tube will heat.
11. Observe the temperature of the water every 15 seconds as the nut burns, until the nut has been consumed. Record the final, highest reading.

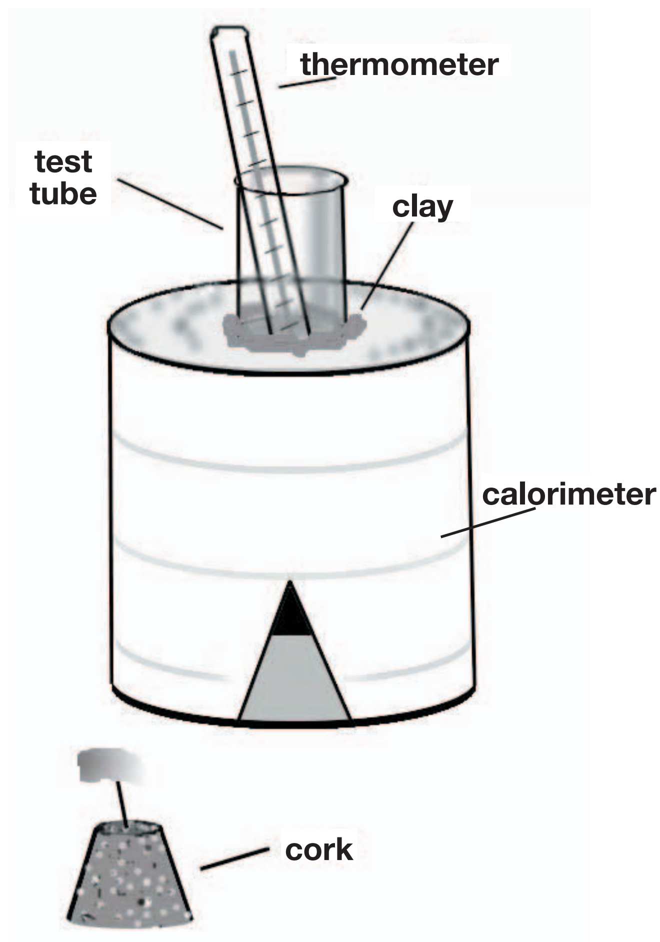



**FIGURE 1. LAB ACTIVITY SET UP**

12. After the nut has burned, determine the number of calories of heat the nut produced using this formula: Calories = volume of water in ml × temperature change (°C) (final temperature – initial temperature), 1 ml of water is assumed to be equal to 1 gm of water for this activity.
13. Complete the Data Table for each nut you burn. The class may share its data to expand the information available on the data sheets.
14. Create 3 bar graphs showing:
    a) the number of calories one peanut, one Brazil nut, etc. produced;
    b) the number of calories per gram produced by each kind of nut;
    c) the average number of calories produced by each kind of nut compiled from the class information.
15. Create a line graph plotting the mass of the nut on one axis and the number of calories it produced on another axis. Use several nuts to plot this.

## DATA TABLE 1. Temperature and Calorie Measurements for Various Nuts

| Type of Nut | Mass of nut (grams) | Initial Temp (° C) | Final Temp (° C) | Calories | Calories per gram |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

## DATA SUMMARY

1. Which kind of nut produced the most calories? ______________________________

2. According to your data, does the mass influence the number of calories produced? ______________

3. Would burning peanuts be a good source of energy? Explain using reasons that include the costs and benefits of burning peanuts.

______________________________________________________________

______________________________________________________________

## Assessment Questions

1. Using Table 1 from the Reading Passage, list cities in a new chart ranking them from landfills with the largest potential for landfill gas to the smallest.

| | | |
|---|---|---|
| 1._______________ | 10._______________ | 19._______________ |
| 2._______________ | 11._______________ | 20._______________ |
| 3._______________ | 12._______________ | 21._______________ |
| 4._______________ | 13._______________ | 22._______________ |
| 5._______________ | 14._______________ | 23._______________ |
| 6._______________ | 15._______________ | 24._______________ |
| 7._______________ | 16._______________ | 25._______________ |
| 8._______________ | 17._______________ | 26._______________ |
| 9._______________ | 18._______________ | 27._______________ |

Which 5 cities would be the best choice for an LFG to electricity plant? Which 5 would be the least productive based on this Table 1?

| **5 Best:** | **5 Worst:** |
|---|---|
| 1._______________ | 1._______________ |
| 2._______________ | 2._______________ |
| 3._______________ | 3._______________ |
| 4._______________ | 4._______________ |
| 5._______________ | 5._______________ |

2. What is your opinion about cities investing money to capture landfill gases to provide electricity?

____________________________________________________________

____________________________________________________________

____________________________________________________________

3. Landfill gas is the end product of chemical reactions occurring in trash. What positive environmental outcome might occur from trash after all?

____________________________________________________________

____________________________________________________________

____________________________________________________________

## Multiple Choice Questions

1. Every year each Texan discards this much trash:
   a) 1,000 lbs.
   b) 150 lbs.
   c) 2,000 lbs. (1 ton)
   d) 50 lbs.

2. Trash can be considered a form of:
   a) wind energy
   b) photovoltaic energy
   c) hydroelectric energy
   d) biomass

3. The gas formed in a landfill is a combination of:
   a) $CH_4$ & $O_2$ (methane & oxygen)
   b) $CH_4$ & $SO_2$ (methane & sulfur dioxide)
   c) $CH_4$ & $CO_2$ (methane & carbon dioxide)
   d) $CH_4$ & $CI_2$ (methane & chlorine)

4. Methane can be converted to:
   a) a fuel additive
   b) plastics
   c) chlorophyll
   d) electricity

5. Texas LFG project(s) is/are located in:
   a) Big Bend
   b) Brownsville
   c) Panhandle
   d) Austin

6. A calorimeter measures:
   a) your weight and computes calories
   b) fat only for loss in diet
   c) energy released from food
   d) methane in compost

7. Biomass can be:
   a) trees
   b) garbage (food)
   c) paper
   d) all answers a, b, and c

8. Burning a nut is:
   a) not possible
   b) an indirect use of biomass
   c) an unusual activity
   d) a direct use of biomass

9. A good candidate for landfill energy recovery is:
   a) Padre Island
   b) Big Bend
   c) Littlefield
   d) Houston

10. Because collecting and burning landfill gas contributes to global warming, which of the following offers the best solution?
    a) collecting and flaring landfill gas.
    b) making electricity from LFG.
    c) burning the trash itself because that returns carbon dioxide to the atmosphere to be used by trees and other plants.
    d) none of the above.

## Follow Up Activity "A" – Making Landfill Gas

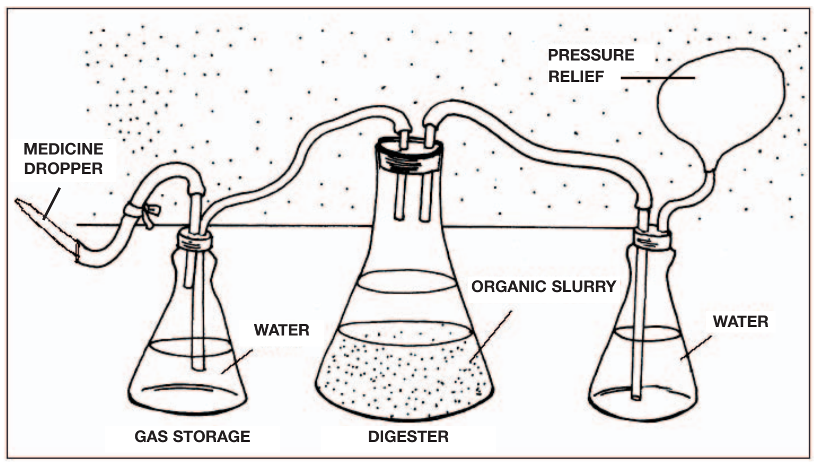
Methane gas is a by-product of decomposition that takes place in sanitary landfills. This process can be modeled in the classroom and landfill gas can be produced in a relatively short time (a few weeks at most).

### Materials:

- three flat-bottom flasks
- petroleum jelly
- organic slurry (manure, grass clippings, kitchen waste, etc.)
- sandwich bag
- three rubber stoppers
- 6 pieces of glass tubing
- 1.5 m clear aquarium tubing
- medicine dropper
- clamp
- rubber band

### Procedure (Wear goggles and observe all safety precautions.)

1. The large flask is the digester. Add about 250 mL of the organic slurry to this flask.
2. Insert two short pieces of glass tubing into a two hole stopper. Use the petroleum jelly to lubricate the glass tubing before inserting. (Your teacher may have prepared the stoppers before hand.) Insert this stopper into the digester.
3. One of the smaller flat-bottom flasks is the gas storage container. Obtain another two hole stopper and insert one long and one short piece of glass tubing into the stopper. Add 100 mL of water to this flask and insert the stopper. The bottom end of the longer glass tubing should be below the water level. Connect the longer tube to one of the tubes in the digester with aquarium tubing. Connect a shorter piece of aquarium tubing to the other tube in the gas storage container. Insert the medicine dropper into the other end of the short piece of aquarium tubing. Attach the clamp between the collector and the dropper.
4. The other 250-mL flask is the pressure relief system. Insert one long and one short piece of glass tubing into the other rubber stopper. Set it up just like the gas storage container, except attach the sandwich bag to the short glass tube using a rubber band to make a gas tight seal.
5. Set the entire apparatus in a warm place, such as a sunny windowsill. Observe it carefully over the next few days. When bubbles are seen in the two smaller flasks and the plastic bag starts to inflate, the apparatus is ready to test for landfill gas.
6. Carry the entire apparatus to the workbench. Light a match and open the clamp so that gas escapes from the medicine dropper. Ignite the gas with the match.




SOURCE: ASSOCIATION OF VERMONT RECYCLERS

## DATA ANALYSIS

1. What happened when you tried to ignite the gas being produced?

______________________________________________

______________________________________________

2. What purposes does the water in the gas collector serve?

______________________________________________

______________________________________________

3. What is happening in the digester?

______________________________________________

______________________________________________

## Follow Up Activity "B" – Making a Landfill

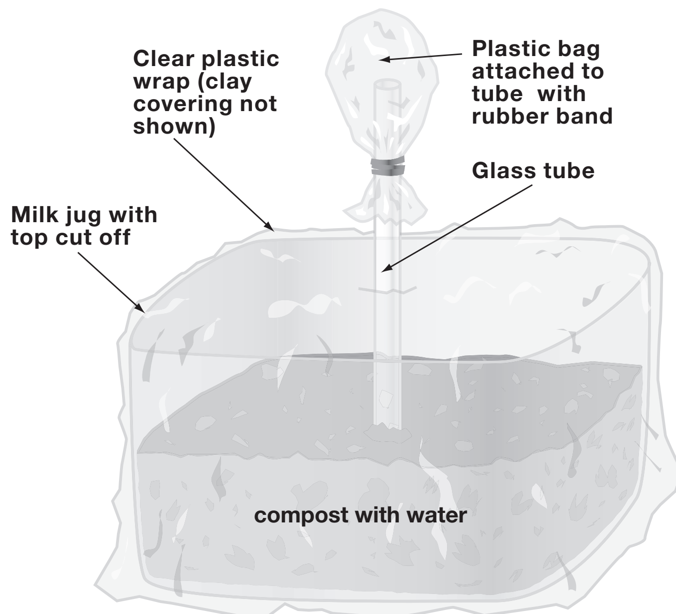
Large landfill operators must trap the gas that is produced and dispose of it properly. You can model a simple landfill and see how much gas it produces.

### Materials:

- one gallon milk jug
- modeling clay (Kleen Klay® or equivalent)
- organic compost
- plastic bag
- clear plastic wrap
- one foot of glass tubing
- scissors
- rubber band

### Procedure (Wear goggles and observe all safety precautions.)

1. Using scissors, cut the top from a one-gallon milk jug. Make the sides about 10 cm high.
2. Add compost until the bottom of the jug is about half full.
3. Add enough water to thoroughly wet the compost.
3. Cover the compost with clear plastic wrap.
4. Insert the glass tubing through the wrap and into the compost.
5. To model what landfill operators do, cover the wrap with a thin layer of modeling clay. Make sure the clay completely seals to the sides of the jug and to the tubing.
6. Attach the plastic bag to the top of the glass tubing with a rubber band.
7. Place the apparatus in a warm place and observe for a couple of weeks.




### DATA ANALYSIS

1. What happened to the plastic bag after a couple of weeks?

_______________________________________________

_______________________________________________

_______________________________________________

2. Describe what is happening in the "landfill."

_______________________________________________

_______________________________________________

# TEACHER ANSWER KEY

## Understanding the Reading Passage

1. 656,562 tons or over 1.2 million pounds; answers will vary by community, but the basic calculation is 1 ton per person.
2. 393,937 tons or nearly 8 million pounds, answers will vary by community, but the basic calculation is 60% of the total community waste.
3. One component of landfill gas is methane (the primary component to natural gas) which is a destructive greenhouse gas. Burning methane for energy prevents it from being released into the atmosphere thereby reducing its contribution to greenhouse gases.
4. home and commercial heating, electrical generation, and pipeline or feedstock gas

## Lab Activity Data Summary

1. Answers will vary based on the nuts burned.
2. Answers will vary depending on data collected and the oil content of the nuts burned.
3. Accept students' opinions, as the answer is a judgment. Students can explore the resources required to grow and harvest peanuts as raw material compared to extracting oil or developing renewable resources.

## Assessment Questions

1. Reordering information promotes critical thinking. Students can reassess what the data indicates. Best choices are Houston, Columbus, Plano, Avalon, and Creedmore. Worst choices are Tyler, Laredo, Beaumont, McKinney, and Corpus Christi.
2. Accept students' answers. Example: We would be wasting the methane gas by not harnessing it for energy, and it would be polluting the atmosphere.
3. We would get electricity from the gas and compost from the decomposed materials, as well as reduce pollution.

## Multiple Choice Questions

1 c; 2 d; 3; c; 4 d; 5 d; 6 c; 7 d; 8 d; 9 d; 10 b (best answer)

## Follow Up Lab "A" Data Analysis

1. The gas ignited and burned cleanly.
2. The water prevents gas from flowing back into the digester and also absorbs some carbon dioxide.
3. Organic materials are decomposing and producing landfill gas.

## Follow Up Lab "B" Data Analysis

1. The bag inflated.
2. The organic materials are decomposing and producing landfill gas.

## Vocabulary Definitions

**biomass** – plant and animal materials that have chemical energy stored in their organic molecules; examples include wood, hay and vegetables

**calorie** – heat required to raise the temperature of 1 gram of water one degree centigrade

**chemical energy** – one form of energy based on molecular composition and status; light, heat, mechanical, chemical, electrical, and nuclear forms of energy exist and can often easily be converted one to another

**decompose** – to separate into constituent parts or elements or into simpler compounds; to rot or to decay

**direct use of biomass** – burning biomass directly, such as burning the nut in the activity

**generator** – machine for converting mechanical into electrical energy

**greenhouse gas** – any gas that has the ability to trap heat at Earth's surface thus raising the global temperature

**indirect use of biomass** – allowing biomass to decompose and burning the methane gas collected from the decomposed materials

**landfill** – essentially a big hole in the ground where municipal waste is stored; landfills are strictly regulated by federal and state law

**LFG** – landfill gas, a mixture of methane and carbon dioxide, that is created from decomposition of landfill biomes, like food scraps or newspapers

**methane** – a combustible compound of carbon and hydrogen; the primary component in natural gas

**natural gas** – a mixture of 80 to 99% methane along with small amounts of ethane, propane, and sometimes a trace of helium

**perforated pipe** – pipe pierced with holes

**potential energy** – energy possessed by virtue of its state (not its motion); unlit fuel has potential energy

# InfinitePower.org

**Financial Acknowledgement** This publication was developed as part of the Renewable Energy Demonstration Program and was funded 100% with oil overcharge funds from the Exxon settlement as provided by the Texas State Energy Conservation Office and the U.S. Department of Energy. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

RENEWABLE ENERGY
THE INFINITE POWER
OF TEXAS

**State Energy Conservation Office**
111 East 17th Street, Room 1114
Austin, Texas 78774
Ph. 800.531.5441 ext 31796
www.InfinitePower.org

Texas Comptroller of Public Accounts
Publication #96-820B (03/05)