

Generating Methane from Waste

Preparation Time: **Easy-to-do** **Moderate** **Extensive**

Grade:	11 – 12
Focus:	Recovering energy from waste
Subject:	Environmental Science, Chemistry
Materials:	See list below
Teaching Time:	One class period to set up the experiment, time for generating gas will depend upon process used
Vocabulary:	Organic waste, methane, slurry, anaerobic, pyrolysis, methane digester

The digestive system of animals such as cattle and sheep contain these bacteria and produce methane gas. A single cow belches out 100 cubic feet of methane each day. The microbes in the guts of termites, which digest wood, also produce methane. Methane is produced for fuel in some parts of the world and burned in **methane digesters**. Methane gas is a greenhouse gas and contributes to global warming. About 12 percent of global warming is attributed to increases in methane in the environment.

The Top Ten Sources of Methane in Our Atmosphere

1. Wetlands	20.2%
2. Rice Fields	19.4%
3. Cud-chewing Animals	14.0%
4. Biomass Fires (such as burning forests)	9.7%
5. Oil & Natural Gas Pipeline Leaks	7.9%
6. Termites	7.0%
7. Coal Mining	6.2%
8. Landfills	6.2%
9. Animal Wastes	5.0%
10. Sewage	4.4%

(Source: *Environmental Literacy, the A to Z Guide*)

NOTE: This experiment may be used as a demonstration during the study of decomposition and composting. Generating gas may take several days.

Learning Objective

Students will:

- understand the energy-producing potential of some solid wastes;
- examine some systems of generating methane from waste;
- construct a model methane generator.

Background

Methane gas is created naturally as a waste product of anaerobic bacteria living in water-logged soils and wetlands and also in human-produced environments such as rice paddies and landfills.



In China and India, there are millions of mini-power plants that use methane gas.

Source: Environmental Literacy, the A to Z Guide

Once buried, **organic wastes** decompose **anaerobically**, which means that they decompose without oxygen. **Pyrolysis** is the chemical change as a result of an increase in temperature that produces heat. Carbon dioxide, methane, ammonia and hydrogen sulfide gases are all produced as microorganisms break down waste. NOTE THIS DISTINCTION: This lesson deals with organic wastes. Inorganic wastes *may* decompose eventually, if given enough oxygen, light and time. However, they do not decompose in a landfill where they are sealed off from oxygen and light.

Trapped beneath the landfill surface, the gas by-products of organic waste decomposition become potential health and safety threats if not properly vented. To avoid explosions or lateral migration of methane beneath the surface of the landfill, vents are installed to reduce pressure build-up of the gases.

Methane is the largest component of natural gas. If the landfill volume is great enough (at least one million tons), the methane produced can be captured, purified by removing carbon dioxide and water and sold to gas utility suppliers. Capturing methane from landfills may not turn a profit, but it can help to defray the landfill's operating costs. There are many methane recovery systems operating or under construction in the United States and a great many more landfills large enough to handle a methane recovery system.

Spartanburg's BMW automobile manufacturing facility has become the first direct use, non-utility company in South Carolina to recycle landfill methane gas as a source of energy in over two decades, and is the only such facility now operating in the state.

Waste Management, Inc. (WMI), the largest waste handler and recycler in the world, supplies the

methane gas from its Palmetto Landfill to Ameresco Energy Services. Ameresco cleans the methane, processes and compresses it and delivers it nearly 10 miles to the BMW facility.

BMW has signed a 20-year purchase contract for the gas, and will use it to fuel four plant turbines. The turbines generate electricity and heat water, supplying approximately 20 percent of the facility's energy needs. This will ultimately reduce the amount of fossil fuel combusted at the 2.5 million square foot facility and replace it with a stable supply of renewable energy.

The project has an equivalency environmental benefit of removing 61,000 cars a year from the highways, every year, as well as planting 40,000 trees per year and an energy equivalency value of saving 80,000 to 100,000 barrels of crude oil each year the project is in operation.

According to an article in *Waste Age* magazine, "The Clean Air Act," November 1993, the United States Environmental Protection Agency (EPA) has proposed new performance standards for new municipal solid waste landfills and emission guidelines for existing facilities under Section 111(b) of the Clean Air Act. This was in response to EPA's findings that municipal solid waste landfills can be a major source of air pollution that contribute to ozone problems, air toxics concerns, global warming and potential explosion hazards.

The EPA conducted a study of landfills to determine the methane generation rate constant and the potential methane generation capacity of the refuse. Based on this data and other assumptions, EPA estimated that the baseline (1987) emissions from the 7,124 existing landfills in the U.S. was 15 million mg/yr of methane and 300,000 mg/yr of other non-organic compounds that occur in landfill gas including benzene,



Methane gas is defined as a colorless, odorless, flammable and explosive gas produced by decomposing garbage and other organic materials.

Source: Recycle South Carolina Glossary, 1997

trichlorofluoromethane, trichloroethylene, vinyl chloride, toluene and perchloroethylene. These predictions do not include emissions from the some 32,000 landfills closed prior to 1987.

Because of emissions concerns, EPA is considering the regulation of “municipal landfill gas emissions” in total.

Materials

- safety glasses
- fume hood (if using heat source)
- three Earlenmyer flasks (one 500 ml, two 125 ml)
- a lubricant such as petroleum jelly
- organic slurry of manure or ground grass clippings, etc. (from a compost pile)
- balloon (blow it up several times to stretch it out, this makes it easier to inflate)
- three rubber stoppers (these may be pre-drilled)
- one foot of glass tubing
- three feet of surgical tubing (or any flexible, large diameter tubing that can be attached to glass tubing)
- the nozzle from a medicine dropper
- one pinch clamp
- a drill to bore a hole in rubber stopper (you may have pre-drilled stoppers)

Learning Procedure

1. Review the background material included with this lesson with the class. Explain that the students will create a methane generator.
2. Refer to the illustration to help with setting up the methane generation/collection apparatus. Wear safety goggles. This experiment must be properly constructed. Your system must be well-sealed. Any leaks will result in a lack of gas pressure. *(You will want to practice this experiment and have students assist you in*

demonstrating the experiment for the class, if enough equipment is available, you may have students set up several stations.)

3. Wear safety goggles while setting up and conducting this experiment. Bore two holes in each rubber stopper or use a stopper with two holes already in place.
4. Run a tube from the flask representing the landfill to a gas storage container. *(NOTE: Make sure all connections are tight. Use petroleum jelly or Amogel on stopper holes. Keep tubing to a minimum. Use large diameter tubing.)* The storage container’s stopper should have two holes, one for the tube coming from the landfill flask *(the large flask)* and one for a nozzle and clamp – this is your flare.
5. Run a tube from the large flask representing the landfill flask to the third flask. This is the pressure relief system. Attach a second tube to the third flask and connect a balloon that’s been blown up several times. Make sure the tube from the landfill flask extends down into water *(see illustration, fill your gas collecting flasks to near capacity with water)*. This arrangement will prevent an excess of gas from feeding back into the landfill flask.
6. Fill the large flask about three-fourths full with an organic slurry *(i.e. manure and ground grass clippings, etc. mixed with water until a thick, but pourable, consistency is reached)*. This flask will represent the landfill. Keep it warm. In the classroom, keep it away from any air-conditioning. Warmth from a sunny window will help. You may keep this set up under a fume hood.
7. It will take days, maybe weeks, before gas is produced. Keep the slurry warm to speed production. As gas is produced, the balloon is inflated.



Animal waste conversion is defined as the process of obtaining gas and other materials from animal waste.

Source: Recycle South Carolina Glossary, 1997

Optional Procedure to Speed Up Gas Production

1. Set up as before only *without* the second flask, which involved the flare.
2. Let the slurry (compost and manure) set overnight and then apply continuous heat and stirring. (Use a hot plate set on about 3 or 4.) This should produce gas in about 20 minutes. You should see the balloon inflate.

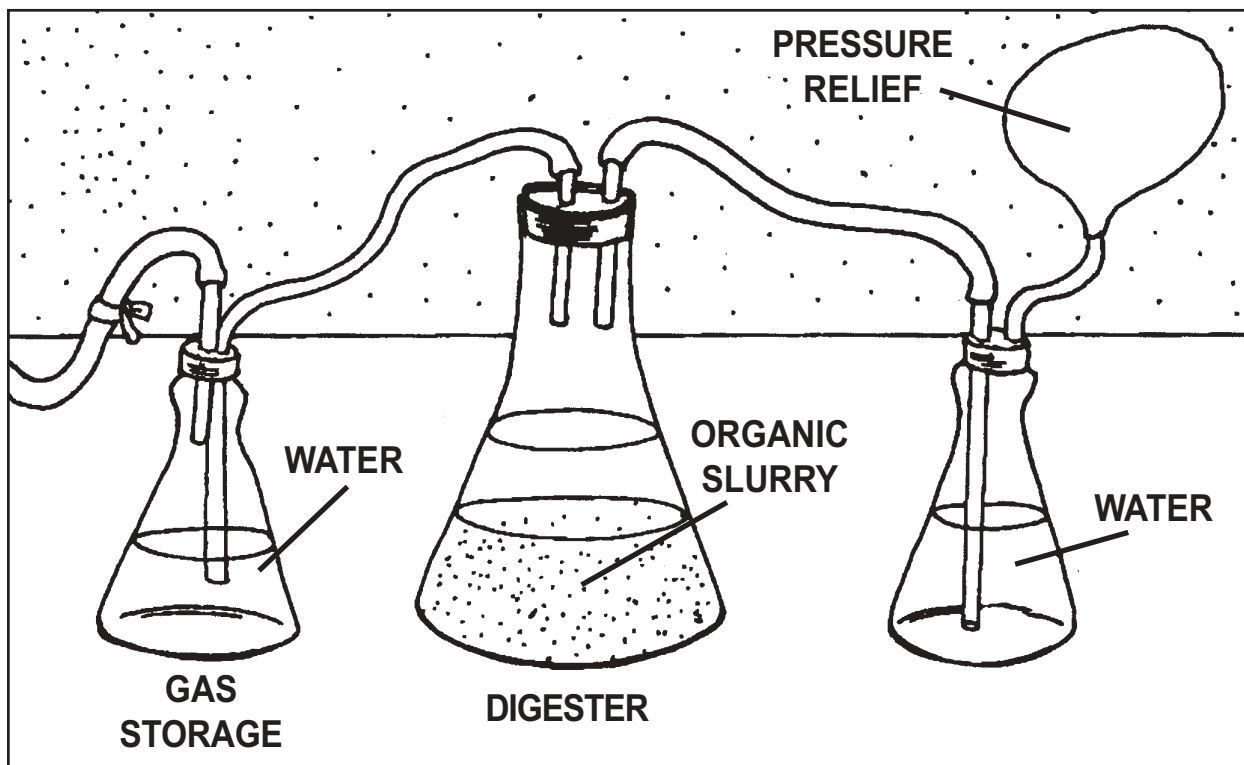
Questions for the Class

1. What is methane?
2. How is it produced?
3. List materials that can be used to generate methane.
4. Describe another means of using solid waste to produce fuel.

Extension Activities

1. Have students research the historical uses of methane gas digesters. For example, in Holland a tarp was placed over a portion of a swamp with a hose running from under the tarp to the house for light and heat.
2. Have students work in teams to build four or five of these three-flask methane generation/capture apparatuses. Have students test different organic wastes. Which produces the most gas the fastest? Which waste produces the best fuel?
3. Research modern methane technology.
4. Study resource recovery technology to learn how industrial fuel is created from solid waste by pyrolysis.

Methane Digester Model



Sun Bathing

Preparation Time:

Easy-to-do

Moderate

Extensive

Grade: 9 – 12

Focus: How solar water heaters work

Subject: Science, Environmental Science

Materials: See list below

Teaching Time: Two class periods

Vocabulary: Solar collector, passive solar, active solar

Materials

To make a model solar water heater, you'll need:

- cardboard or wooden box (approximately 36" x 48" about 8" deep);
- rigid foil-faced insulation board (enough to line box);
- flat black spray paint;
- aluminum-backed tape;
- utility knife;
- garden hose;
- 6 to 8 mil polyethylene;
- thermometer;
- bucket or gallon plastic jug;
- watch or clock that measures seconds;
- cellophane tape;
- permanent marker;
- work space outside;
- site outside with a faucet and full sun at the time you'll be conducting the experiment.

Learning Objective

Students will create a model solar water heater.

Background

Using the sun to heat water for household purposes (laundry, bathing, cleaning) is not a new idea. In California and Florida, simple solar water heaters were manufactured and sold as early as 80 years ago. The theory is simple. Cold water is pumped from a supply source – a well or municipal system – to a south-facing solar collector. This collector is a panel, often mounted on the roof, that is designed to collect solar energy and transfer that energy to heat the water. The water travels through a network of pipes in the collector and, as the sun shines, the water heats up. The hot water then circulates to an insulated storage tank, much like a traditional water heater, where it is kept warm until used. Water temperature in the collector can reach 180°F; most household uses require only about 120° or less.

There is increasing acceptance of solar energy. After all, solar energy is readily available throughout the country, the technology for putting the sun to work is developed and the sun's energy is free. The sun's energy is clean and nonpolluting.

The two basics types of solar energy systems in use are **passive and active solar systems**. Passive solar systems are relatively inexpensive, have no maintenance requirements and last indefinitely because there are no moving parts to wear out. They do not provide for long-term heat storage nor for automatic control of the heat.

Active solar systems are more expensive because they require the installation of special equipment.



An affordable housing development in Dallas, Texas, has slashed utility bills by \$450 a year per dwelling by incorporating solar heating and efficient appliances that add only \$13 a year to mortgage payments.

Source: WorldWatch Institute

Active systems do provide for heat storage and they do have automatic controls.

Passive Solar Systems

In a passive solar heating system, the structure is designed to capture heat during daytime hours and to gradually release that heat during night time hours. It has no means to transfer the heat energy from one room to another except by natural heat flow. Buildings made from stone, brick, concrete walls and ceilings or floors soak up heat and release it when the outside temperature drops. Window shutters and extra insulation slow down the heat transmission from the building. These systems provide large amounts of free energy.

Active Solar Systems

An active solar system consists of equipment to trap the sun's heat and to use the heat for hot water and/or space heating. These systems usually have automatic controls.

The illustration below shows the components of an active system.

The collector is the means by which the system traps the sun's energy. It is normally mounted on the roof. In its simplest form, the solar collector is nothing more than a flat box with a clear piece of plastic or glass over its surface. The sun's energy flows through the cover and is trapped inside.

The collector usually has tubes inside which contain a heat transfer medium, this may be water. This liquid is heated and circulated through the system by pumps. The heated liquid is pumped to a storage tank, usually a tank of water. When heat is needed, pumps circulate the hot liquid to a heat exchanger, a device that looks like a car radiator.

Warm water is pumped through the coils and air from the building is blown across the fins on the coils and warmed for heating.

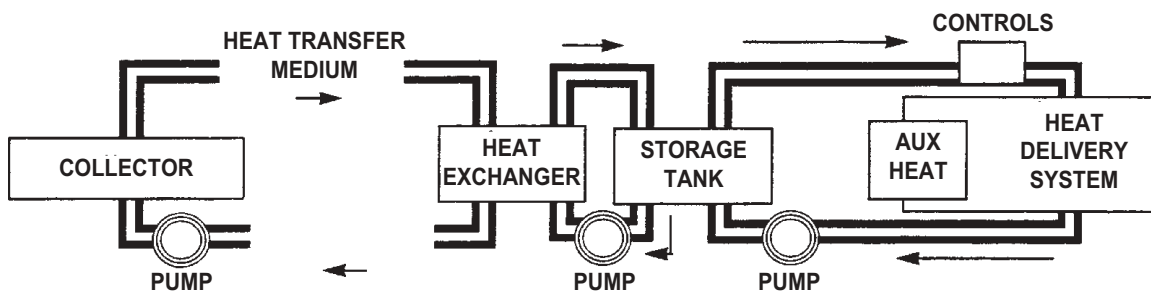
This is a forced heat-delivery system. These systems also have controls that work much the same as thermostat controls. Because the sun doesn't shine 100 percent of the time, the system has auxiliary heat from a conventional source.

Learning Procedure

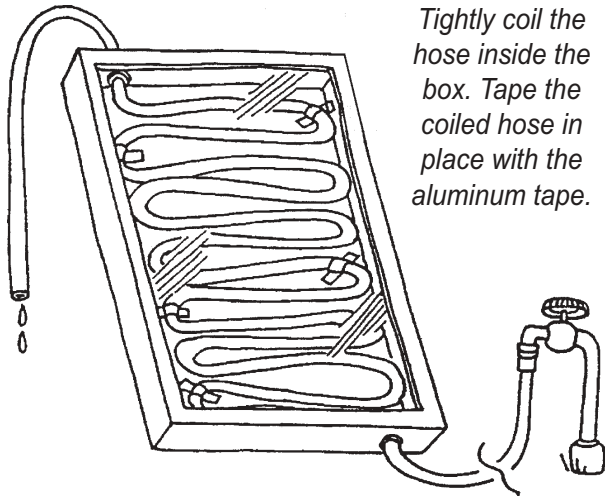
Making a model flat plate solar collector can be done as a class project or several groups can assemble a collector and test it. It is best to allow one class period to assemble the materials and make the collector and another class period to perform the experiment.

Day One: Making the Model

1. To assemble the model solar water heater, insulate the inside of your box (no top on the box) with the insulation board. You will need to pre-cut the board to fit the bottom and sides of the box. Please pre-cut this for students. Place the insulation on the bottom first, then sides and tape in place with the aluminum tape. This is done to help retain the heat.
2. On the side panels of the box, cut small holes large enough to poke the garden hose through (see illustration). The holes should be cut in the short sides of the box to allow the hose to travel through the box.
3. Spray paint the inside of the box flat black and allow to dry.
4. While the box is drying, cut a piece of polyethylene large enough to cover the top of



The major components of a simple solar energy system for hot water and space heating.



the box plus a selvage of about two inches around. This plastic will be used later as the glazing or clear window cover for the collector. Do not install it yet.

- Put the end of the garden hose through one of the side holes and pull through the box and out the other hole. Leave about 12 inches of the hose sticking out of one end of the box. Secure this end of the hose to the outside of the box at the opening, sealing the opening at the same time (see illustration).
- Tightly coil the hose inside the box. Tape the coiled hose in place with the aluminum tape and secure the other end of the hose to the box, sealing the hole. Be sure to leave enough hose extending from the box to reach the faucet and to allow your model collector to be placed in full sunlight.

Day Two: Testing the Model

- Ask the Class:** Before we hook up the collectors to the faucet, will the rate of flow affect how hot the water gets? Why? *(Yes, the rate of flow will determine how long the water is exposed to the heat. As the water flows through the pipes, it warms up with energy from the sun. The longer it stays in the pipes, the more heat it can absorb.)*

For this reason, it is important to set the rate of flow of the water. To do this, use a one gallon

jug or bucket, and with a permanent marker, mark lines on the side for each quart level.

Hook your collector to the faucet. Place the marked bucket or jug to collect the water at the end of the collector. Turn the faucet on at a low volume and measure the amount of water as it comes out of the collector. Time the flow in seconds and adjust the faucet so that **the rate of flow equals one quart every three minutes.**

- To Test the Collector:** First, test the collector without the plastic glazing. Set the collector in full sun at an angle as close to perpendicular to the sun's rays as possible. Measure the temperature of the water as it leaves the faucet and record.
- Connect the hose to the collector, turn on the water, adjust the rate of flow to one quart every three minutes, and let it run during the experiment.
- Measure the temperature of the water as it leaves the collector every minute for 15 minutes and record.
- Ask the class: What effect will adding a cover or glazing have on the temperature of the water? Why? *(The temperature will increase because the glazing will hold the heat inside the box.)*

Now test the collector with the glazing. Tape the plastic cover over the box and test as before. What effect did the glazing have? Why?

Extension Activity

- Try some variations to your flat plate solar water heater model. Double the rate of flow and repeat the test. What affect does this have and why?
- Try lining the inside of your box with different colors – mask the flat black paint with colored poster paper. How does color affect the absorption of heat?

Model Solar Collector: Results Record

TIME	TEMPERATURE (without glazing)	TEMPERATURE (with glazing)
1 Minute	Temperature:	Temperature:
2 Minutes	Temperature:	Temperature:
3 Minutes	Temperature:	Temperature:
4 Minutes	Temperature:	Temperature:
5 Minutes	Temperature:	Temperature:
6 Minutes	Temperature:	Temperature:
7 Minutes	Temperature:	Temperature:
8 Minutes	Temperature:	Temperature:
9 Minutes	Temperature:	Temperature:
10 Minutes	Temperature:	Temperature:
11 Minutes	Temperature:	Temperature:
12 Minutes	Temperature:	Temperature:
13 Minutes	Temperature:	Temperature:
14 Minutes	Temperature:	Temperature:
15 Minutes	Temperature:	Temperature:



Investigate the availability of solar water heaters in your area. Do local builders recommend them?

Nuclear Power in Our State

Preparation Time:	Easy-to-do	Moderate	Extensive
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Grade:	9 – 12
Focus:	The story of nuclear power in South Carolina
Subject:	Science, Social Studies, History
Materials:	Handouts included with this lesson
Teaching Time:	Several class periods, including student research and writing time
Vocabulary:	Nuclear reactor, nuclear waste

for South Carolina produced by the S.C. Energy Office.

Did You Know?

- More than half (56.5 percent) of South Carolina's electricity is generated by nuclear power.
- Of the 50 states, only Illinois and Pennsylvania consume more nuclear energy than South Carolina.
- Barnwell County is one of three sites in the U.S. where low-level¹ nuclear wastes are stored.
- One gram of waste results from one megawatt-day of nuclear reactor heat energy production. In contrast there is a weight of some 2.5 tons of waste solids and gases from burning fossil fuels such as coal to produce the same amount of heat. That's right! One gram of waste from nuclear power production compared to 2.5 tons of waste and gases from burning fossil fuels. This comparison, however,

does not factor in the dangers of the waste. Nuclear waste, while small in volume, is highly toxic.

Source: *Understanding Radioactive Waste* by Raymond L. Murray

¹ Low-level wastes include gloves, clothing and tools that have been contaminated by radiation.

Learning Objectives

In this lesson, students will:

- explore the history of nuclear power in South Carolina;
- see how much of our electricity comes from nuclear power; and
- examine why some people are concerned about nuclear power.

Materials

This lesson includes a "Timeline of nuclear power in South Carolina" handout for students to read. The timeline was compiled from articles that ran in *The State* newspaper and is supported by excerpts from the chapter on nuclear energy from the *Energy Factbook: A Resource*



In the United States, 103 nuclear power plants generate 20 percent of total electrical power consumed annually. In many other industrialized countries, this fraction is between 30 percent and 40 percent. In France, the world's most nuclear-power dependent nation, the atom generates more than 70 percent of all electricity.

Source: *American Nuclear Society*

Timeline of Nuclear Power in South Carolina

- 1950** Almost eight years after the first controlled nuclear chain reaction took place in 1942, it was announced that South Carolina would be the site for a \$260 million nuclear weapons plant. The Savannah River Site would occupy 300 square miles (192,000 acres) of rural farmland and was heralded as a boom for the state's economy.
- Nuclear energy represented the largest industry South Carolina had ever known. The plant would produce plutonium and tritium to be used in the country's national defense program. *The State* newspaper reported on its front page that the plant selection moved South Carolina to the "forefront in the battle against the Communist menace."
- 1954** Congress passed the Atomic Energy Act and President Dwight D. Eisenhower began the Atoms for Peace Program to promote the commercial use of nuclear materials for peaceful purposes.
- 1957** Carolina Power & Light (CP&L), Duke Power and S.C. Electric & Gas (SCE&G) joined with Virginia Electric and Power Company to form the Carolinas-Virginia Nuclear Power Associates. This group agreed to build the Parr Nuclear Power Facility, a small, 17-megawatt reactor to produce electricity. This was designed as a research and development project.
- 1963** The Parr Nuclear Power Plant, the first nuclear power plant in the Southeast, began operation. It was located 25 miles northwest of Columbia in Parr, South Carolina.
- 1966** Carolina Power & Light began construction on the Robinson reactor, a 665-megawatt nuclear plant in Hartsville.
- 1966** Duke Power began plans to build three reactors that would comprise the Oconee Nuclear Plant.
- 1967** The Parr Nuclear Reactor Experiment was shut down and sealed shut. The tiny reactor was determined not to be economical to operate. Each of the power companies involved in the project went on to pursue nuclear power.
- 1967** The Federal Atomic Energy Commission (AEC) began looking for a site to handle spent nuclear fuel reprocessing. In May, the South Carolina legislature passed legislation to allow spent nuclear fuel reprocessing in the state.
- The AEC selected Allied Chemical to build the Barnwell Nuclear Fuels Plant in Barnwell, South Carolina. At the time, spent fuel reprocessing was an important component in nuclear power. The process allowed nuclear fuel rods to be recycled and used again.
- 1969** Duke Power began planning a two-reactor nuclear power plant, the Catawba Plant in York County. These were scheduled for completion in 1983 and 1985.
- 1971** Carolina Power & Light's Robinson reactor near Hartsville began operation.
- 1971** Construction began on an \$80-million facility – Barnwell Nuclear Fuels Plant – to reprocess nuclear fuels.
- 1973** Chem-Nuclear Systems opened as a low-level nuclear waste burial site in rural Barnwell County.
- 1973** The oil embargo and fossil fuel crisis hit. This focused attention on America's dependence on foreign sources for energy and our dependence on fossil fuels.
- 1973** The first Duke Power Oconee nuclear reactor came on line.
- 1973** Duke Power began plans for a three-reactor nuclear power facility in Cherokee County.

- 1973** S.C. Electric & Gas began planning for a 900-megawatt nuclear reactor near Jenkinsville in Fairfield County. Santee Cooper agreed to purchase one-third of the plant's generating capacity.
- 1973/1974** Duke Power's Oconee Units 2 and 3 begin generating electricity.
- 1977** President Jimmy Carter announced a moratorium on commercial spent fuel reprocessing. This meant that the Barnwell Nuclear Fuels Plant could not be opened as planned.
- Utilities had planned from the beginning of nuclear power operation to one day send their accumulating spent reactor fuel rods to privately operated reprocessing centers for recycling. Used fuel was to be recycled to capture uranium and plutonium that could be reused in a plant's reactor.
- Utilities had never considered spent fuel as a waste product; they thought of it as a valuable, reusable commodity. With the moratorium, nuclear plants had become producers of a dangerous waste product.
- President Carter declared the ban because of a growing concern about the environmental dangers of reprocessing and to guard against terrorist theft of deadly plutonium gleaned from reprocessing. Spent fuel that had been building up at reactor sites since plants started operation, had to be stored indefinitely.
- 1979** A reactor at the Three Mile Island Plant in Pennsylvania malfunctioned.
- New safety requirements issued by the Nuclear Regulatory Commission were estimated to double the cost of building a nuclear plant.
- 1983** Duke Power canceled construction of nuclear power plants in Cherokee County.
- 1984** S.C. Electric & Gas began operation of the V.C. Summer Nuclear Plant near Jenkinsville.
- 1985** Duke Power's Catawba Nuclear Plant began generating electricity.
- 1986** The S.C. Legislature passed legislation to close the Barnwell Nuclear Waste Disposal Site in 1992.
- 1992** The Nuclear Regulatory Commission declared the V.C. Summer Nuclear Plant in Jenkinsville as one of the four safest in the nation.
- 1992** The S.C. Legislature extended the date for closure of the Barnwell Nuclear Waste Disposal Site until 1995.
- 1995** At Governor David Beasley's request, the S.C. Legislature re-opened the Barnwell Nuclear Waste Disposal Site to the entire country with no date for closure.
- 1998** The Chem-Nuclear Barnwell Nuclear Waste Disposal Site received and buried 99.5 percent of the radioactivity from low-level waste throughout the nation. Barnwell received the nuclear waste of 38 states.
- 1999** Governor Jim Hodges created the S.C. Nuclear Waste Task Force for the purpose of ending South Carolina's role as the nation's nuclear dumping ground.
- Nearly 57 percent of South Carolina's electricity is generated by nuclear power. There is still controversy about our state's nuclear involvement. The state's four nuclear power facilities, the Barnwell Low-level Nuclear Waste Burial Site, the Savannah River Site, spent nuclear fuel and the transport of nuclear materials through our state are issues still causing debate.
- Nearly 25 years after the Three Mile Island nuclear accident, not a single nuclear plant construction permit has been brought before the Nuclear Regulatory Commission. No one has proposed building a nuclear plant in the United States since 1978. Across the country, 103 nuclear power plants generate 19 percent of the nation's electricity.

Learning Procedure

1. Introduce the topic of nuclear power using the pages from the *Energy Factbook* and the *Timeline* and have the class participate in a discussion.

Questions for discussion include:

- What are the pros and cons of nuclear power? (Pros include reduced pollution from conventional power generation that burns fossil fuels, less dependence on nonrenewable fossil fuels and economic power sources. Cons include nuclear waste disposal and safety concerns.)
 - What is the difference between a nuclear power plant and the Savannah River Site? (*A nuclear power plant is owned and operated privately. These facilities use nuclear fission to create the heat source that is used to create the steam that turns the turbine that generates electricity. The Savannah River Site is a federal government facility that produces materials to be used in producing nuclear weapons.*)
 - If South Carolina did not have nuclear power generating facilities, how would we generate the electricity we need? (*There is no single answer to this. Have students speculate on other methods, more coal-fired power plants, more hydroelectric plants, alternative energy sources such as solar, etc.*)
2. Start a nuclear power bulletin board in the classroom. Have students search for books, articles and newspaper clips about nuclear power worldwide and in South Carolina. Be sure to have students distinguish between issues that face the generation of electricity using nuclear power and nuclear weapons production. Discuss how the public might confuse these issues.

Good sources for information on nuclear energy include:

- *Understanding Radioactive Waste* by Raymond L. Murray, Battelle Press, 1989.

- *The State Newspaper* (The Record edition), "The Nuclear State," Saturday April 12, 1980.
 - *The 1993 Information Please Environmental Almanac* compiled by the World Resources Institute, "Cleaning up after the Cold War," p. 129.
 - *Energy for Tomorrow's World* by the World Energy Council, St. Martin's Press, 1993.
3. Ask the following questions and give the appropriate explanations:
 - Ask students to figure out how old they will be in the year 2050.
 - Ask them to describe their lifestyles in the year 2050. (*Many will estimate that they will be working, have a family, own a home, nice cars, etc.*)
 - Ask students to describe what their energy needs would include. (*Most will include heating and air conditioning for a large home, several TV's, computers, other electronics, etc.*)
 - Explain to students that experts estimate that by the year 2050 the world's energy demands will double.
 - Ask "Where will all this energy come from?" (*Remind students that many fossil fuels, particularly oil and natural gas may be in shorter supply and more expensive, also remind them that currently South Carolina depends on nuclear power for much of its electricity.*)
 - Have students write an essay describing their lifestyle in the year 2050 in terms of the energy they will use. Have them include how the energy will be generated, will South Carolina continue to produce nuclear power? If so, where will new plants be located? What will happen to the nuclear waste? Where will nuclear waste facilities be located? If not, what will replace nuclear power?

Nuclear Energy

Excerpts from the *Energy Factbook: A Resource for South Carolina*

Nuclear energy plays a major role in South Carolina's energy picture and holds great promise for our energy future. It offers an alternative to fossil fuels. At the same time, it carries with it the need for responsible use.

What Is Nuclear Energy?

Nuclear energy is energy released by a nuclear reaction. The process of releasing energy from atoms is difficult to achieve. To understand it, you need to know that matter – which is everything that occupies space – is made up of atoms. In the center of every atom is a nucleus. Inside the nucleus are particles known as neutrons and protons. Traveling around the nucleus are electrons.

This diagram of a carbon atom shows an equal number (six) of protons and neutrons in the nucleus. Six electrons circle the carbon nucleus.

When some atoms are bombarded by neutrons they can be made to split, releasing great quantities of heat energy. The process of splitting atoms to release energy is known as **fission**.

When an atom splits, neutrons from its nucleus are shot out at high speeds. They, in turn, cause other atoms to split. A chain reaction is thus set in motion.

The first controlled nuclear chain reaction took place at the University of Chicago on December 2, 1942 under the direction of Enrico Fermi. This event ushered in the **Atomic Age**.

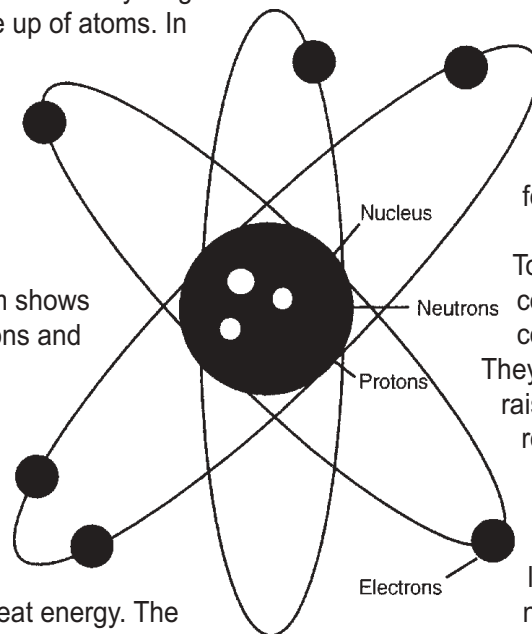
How Nuclear Energy Is Produced

The vast power of nuclear energy can be made to work for us. For example, all nuclear plants convert

the nuclear energy in uranium to electrical energy we can use. When the heat energy produced by fission is transferred to water, it creates steam. The steam powers a generator to make electricity.

How A Nuclear Plant Works

In a nuclear power plant, fission occurs in the nuclear reactor. The heat energy produced by fission is captured to use in making steam to run the plant's generators.



Uranium is the fuel used in nuclear power plants. Uranium pellets are stacked in long, metal fuel rods, which are bundled together to form fuel assemblies.

To regulate the fission process, control rods (steel rods containing boron) are used. They act as "neutron sponges." By raising or lowering the control rods into the reactor, the chain reaction is increased or decreased. For example, when the control rods are lowered, the number of neutrons available for fission is reduced. This slows down or stops the chain reaction.

The heat produced in the nuclear reactor is transferred to water which cools the reactor. The water does not boil because it is under pressure. Water flows through the primary system indirectly heating water in the steam generator to produce steam. The steam spins turbines that generate electricity. Water in a closed system condenses the steam. The steam is then returned to the generator to be reused.

Using Nuclear Energy Responsibly

In a world with limited fossil fuels, many people feel nuclear energy has great prospects. It is

considered to be “clean energy.” Nuclear energy does not pollute the atmosphere because the fuel is not burned.

Two main concerns, however, do persist with nuclear energy – radiation and waste disposal. Every time fission occurs, invisible particles are released. These particles, or radiation, can be harmful. To prevent radiation from escaping the reactor in which it is isolated, many safeguards have been put into place.

U.S. nuclear power plants are tightly regulated to make sure that radiation leakage does not occur. No nuclear facility can be built or operated without a license from the U.S. Nuclear Regulatory Commission (NRC). Plants are carefully monitored by NRC inspectors as well as employees.

Likewise, proper disposal of nuclear waste is essential in the safe use of nuclear fuel as energy. This is especially important to us in South Carolina since Barnwell County is one of three sites in the U.S. where low-level nuclear wastes are stored. Some of the precautions taken in handling nuclear wastes include:

- Burying the waste containers in water-proof trenches;
- Regularly checking nearby water wells to ensure that no radiation has escaped; and
- Closely monitoring the area to make sure that the waste containers remain undisturbed.

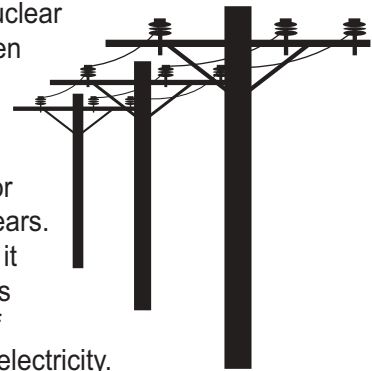
Nuclear Energy in South Carolina


Since the early 1970s, South Carolina has been a leader among states with regard to the use of nuclear power. Of the 50 states, only Illinois and Pennsylvania consume more nuclear energy than South Carolina.

In South Carolina, we have been able to reduce our use of fossil fuels because of our extensive use of nuclear energy. Nearly one-third of the state’s energy needs are currently being met by nuclear energy. About 57 percent of the electricity we produce comes from nuclear power.

With the opening of the Oconee Nuclear Power Plant in 1973, South Carolina became the first state in the South to use nuclear energy for electrical generation. Today, there are four nuclear plants operating in the state. These include the Oconee, H.B. Robinson (Darlington County), V.C. Summer (Fairfield County) and the Catawba Nuclear Power Plants.

South Carolina’s nuclear facilities have proven to be cost-effective investments. The Oconee Nuclear Power Plant paid for itself in just eight years. In its first 10 years, it became the nation’s leading producer of nuclear-generated electricity.





Just do it! Turn off the lights, TV or radio whenever you leave a room to save energy in your home.

Energy Conservation by Design

Preparation Time:

Easy-to-do

Moderate

Extensive

Grade:	9 – 12
Focus:	How home siting and building design can help conserve energy
Subject:	Environmental Science
Materials:	Handouts included with this lesson, cardboard box, bright flashlight
Teaching Time:	One class period, plus student projects
Vocabulary:	Passive solar heating, fixed overhangs

rising in the east, tracking across the wall and roof of your box house, and setting in the west. (See the sun's path in the illustration on the student information sheet.) **Ask:** What difference does the orientation of a house – facing east, west, north, or south – make in siting a home? (It will determine how the sunlight/heat streams into the house.) **Ask:** Can you think of any reasons why you might want to consider which way the house faces? (You may want to avoid intense sunlight in summer and/or use sunlight to help heat your home in winter.) Which direction does your bedroom window face? Do you prefer warm sunlight streaming in in the morning, or would you prefer to have the afternoon sun warm your room? How about light and heat coming in to the kitchen?

Learning Objective

Energy efficient appliances are just the beginning. Today, we have energy efficient options for almost every home fixture and even the home itself. In this project-based activity, students will:

- examine how controlling solar radiation can improve energy efficiency;
- discuss home design for energy efficiency; and
- create their own home design for energy conservation.

Learning Procedures

1. Place the cardboard box on a table so that students can see it. The box will simulate a house. Using a marker, draw in windows and doors. Use the flash light to simulate the sun
2. Hand out the student project information and work sheets and explain to students that they are going to select a lot in a neighborhood, site a house on the lot and make decisions on landscaping and building designs for energy efficiency.
3. Give students at least a week to read the energy-efficient design information and complete the worksheets. Then have students present their ideas to the class. For more advanced classes, have students create a model of their home highlighting energy-efficient designs or prepare simple site blueprints showing the placement of the home on the lot, landscaping and other features.

**DOWN
to Earth**



Lighting accounts for about 20 percent of all electricity use in the country and about 10 percent of electricity use in our homes. The typical household spends about \$90 per year on lighting and most of this is wasted on inefficient incandescent light bulbs. These bulbs are actually heaters in disguise, converting 90 percent of the electricity to heat and only about 10 percent to visible light.

Source: American Council for an Energy-Efficient Economy

Design Considerations for Energy Efficiency

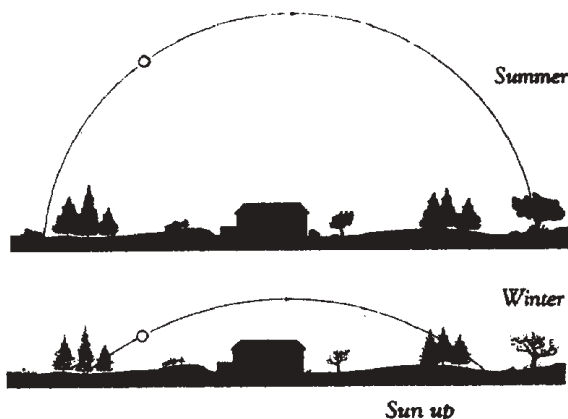
Siting the House

Home orientation – facing north, south, east or west – is important to know when planning the layout of rooms, windows, porches and overhangs and even landscaping to maximize energy efficiency. A house with a large bank of unshaded windows facing due west will be expensive to keep cool in the summer. It is important that selection of the lot be made in conjunction with the design of the house and your preferences for comfort. For example, do you want morning sun streaming into bedroom windows or do you prefer afternoon sun coming into bedrooms while you are out? Do you want to have a sunny kitchen for breakfast? Will intense afternoon sun be a problem for the windows in a family room?

As the sun rises in the east, travels across the sky, and sets in the west, the south side of a home receives solar radiation most of the day; the east side only in the morning; and the west side only in the afternoon. The north side does not receive any radiation.

The north-facing exterior wall is always the coldest wall. To reduce heat losses in winter, the north-facing exterior wall should have high resistance to heat transmission. It should be protected from winds, perhaps by evergreens. A dark color will help absorb the maximum amount of reflected solar radiation. In the summer, the north-facing wall should have some means for drawing in cool air.

The east- and west-facing exterior walls should have more windows than north-facing walls and



have provisions for letting light in or shading. Solar radiation is only available during limited hours of the day, so awnings, blinds, shutters and other light controlling devices are good ideas. Deciduous plants – that drop leaves in the fall – can provide summer shade and let in winter sun.

The south-facing exterior wall is critical. This is the wall that receives the most heat energy from the sun's rays. It is always the hottest wall of the structure. The possible treatment of this wall is dependent on its function and geography – in colder climates its solar radiation can be used for heating and in warm climates it must reflect solar energy to save on cooling costs.

Large window walls can collect solar heat in winter. In summer when shade is needed, awning, overhangs and other controllable devices such as shutter and blinds help. Deciduous trees can provide summer shade as well. Control of south-facing solar radiation can reduce energy costs considerably. A 40-foot-long, 8-foot-high south wall can receive more than 200,000 Btu on a sunny day (five hours of direct sun). For a 120-day heating season with only 50 percent sunshine, that is more than 14 million Btu. These savings are lost, though, if the solar radiation isn't controlled in the summer when air-conditioners are running.

Landscaping

Landscaping can increase energy efficiency by shading hot summer sun and protecting the house from wind. Planting deciduous trees that provide summer shade and then lose their leaves in winter to let warm sun shine in can be beneficial. Evergreens can be used to shield a house from cold winds.

Fixed Overhangs

A fixed horizontal overhang on the south side of a house is a widely used feature associated with passive solar heating systems. An overhang on the south side of a house is used to regulate solar (sunlight and heat) gains on a seasonal basis. Fixed overhangs work by blocking high-angle summer sun while allowing low-angle winter sunlight to reach south facing windows.

TABLE 1: Example Overhang Lengths for Selected Cities in S.C.

Location	Latitude	CASE 1 NAHB Method (feet)	CASE 2 NAHB Method (feet)
Aiken	33.5	2.00 - 1.45	1.25 - 2.90
Anderson	34.5	2.20 - 1.60	1.36 - 3.17
Beaufort	32.5	1.86 - 1.40	1.16 - 2.80
Charleston	32.9	1.50 - 1.90	1.20 - 3.10
Columbia	33.9	1.60 - 2.20	1.40 - 3.30
Greenville/Spartanburg	34.9	1.70 - 2.20	1.40 - 3.30
Greenwood	34.2	2.13 - 1.54	1.33 - 3.08
Florence	34.2	2.13 - 1.54	1.33 - 3.08
Myrtle Beach	33.7	2.05 - 1.47	1.28 - 2.94
Orangeburg	33.5	2.00 - 1.45	1.25 - 2.90
Rock Hill	35.0	2.29 - 1.64	1.43 - 3.28
Sumter	33.8	1.90 - 1.43	1.20 - 2.86

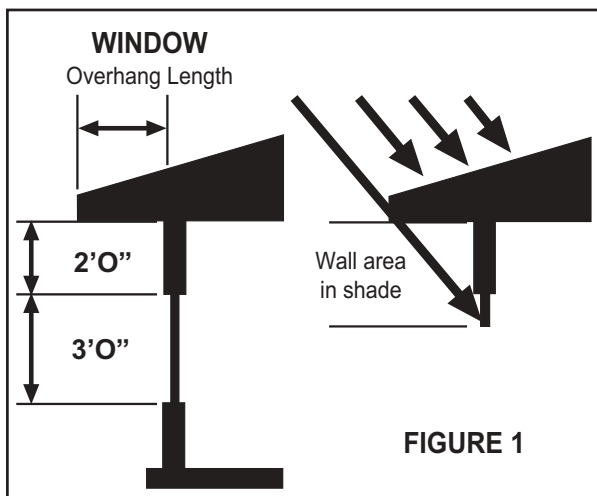
The concerns in designing a fixed overhang are the length and width of the overhang and the size of the separation between the bottom of the overhang and the top of the window. The length of the overhang is the primary factor that determines the period of time that the overhang will shade the window.

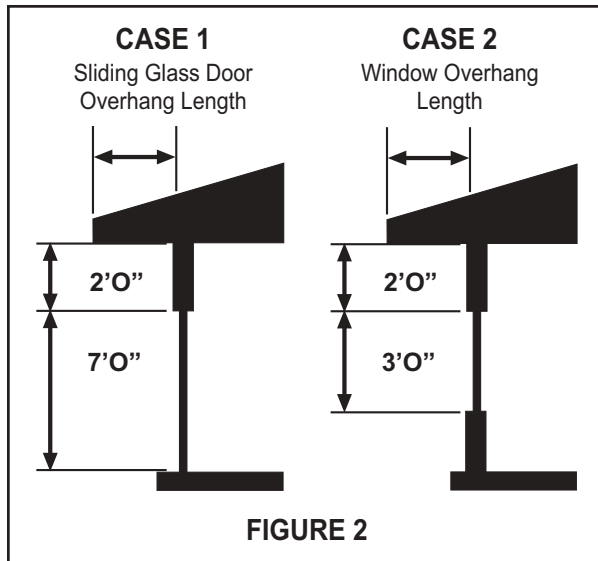
The most effective overhang length will vary among locations, depending on the relationship of the particular site to the sun. For example, a two-foot overhang might shade a window throughout the summer on a house located at 32° latitude but leave the window partially unshaded on the same house at 40° latitude. This is because the summer sun is at a lower altitude angle in northern

latitudes, so a longer overhang will be needed to block the direct sunlight (See Figure 1).

The width of the overhang is another design consideration. The overhang should extend beyond the window on either side to block the lower morning and afternoon sun. The extension of the overhang depends on the window configuration. If the window is narrow and long, the overhang should extend a substantial distance beyond the window on either side to provide full shade. On the other hand, if the window is wide and short, the overhang need only extend slightly beyond the width of the window to shade it.

The heating and cooling needs of the individual residence should be considered in sizing an overhang. An overhang that is sized to provide full shade throughout the entire cooling season will also provide some shading during the heating season. For example, equivalent sun angles occur in September and March, at the fall and spring equinox. An overhang that shades a window in September - a time when you may still run air conditioning in most of the South - will also provide shade in March when the warmth of the sun is desirable. Consequently, it is important to consider the heating and cooling needs of a house in a particular location. An overhang may be totally inappropriate on a house in a cold climate with a large passive solar heating system. The benefit





during the cooling season would be offset by the reduced performance of the passive system during the heating season.

Another factor that should be considered is that overhangs only block direct solar radiation. Indirect and diffuse radiation will still cause heat gains even when a window is fully shaded by an overhang, and diffuse radiation can be a significant source of heat. The average solar radiation received in June by a window that is completely shaded by an overhang ranges from 50 percent to 80 percent of the solar radiation received by the same window without any shading. Thus in warm sunny climates, other shading devices, such as operable shutters, blinds or shades, should be used in addition to a fixed overhang.

There are a number of manual design tools available for sizing fixed overhangs. One method was developed by the National Association of Home Builders (NAHB). It consists of a graph that provides a value for feet of vertical wall in shade per each foot of overhang for various latitudes. The method is easy to use but has a fixed rather than user-defined shading period.

An example of overhang sizing is given in Table 1. The base cases consist of a sliding glass door and a conventional window with separation sizing and height of vertical south-facing glazing defined in Figure 2. Consider the recommendations for Case #1 in Columbia. The NAHB method results in a range of overhang lengths of 1.6 to 2.2 feet. This

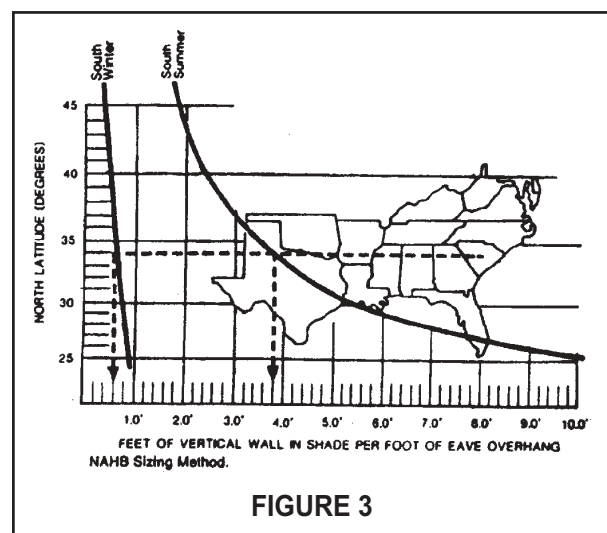
method focuses on keeping the house cool in the summer.

Because of the physical requirements of the building itself as well as aesthetic considerations, an overhang much longer than two feet is rarely justified. Also, a very long overhang may block desired solar heating in the winter and may not offer the best protection from summer heat gain. Keep in mind that because of substantial diffuse sun, other shading devices are needed in addition to an overhang for reduction of heat caused by summer sun.

Figure 3 provides a simplified method of calculating shading requirements on south-facing glazed areas. The graph determines the feet of vertical wall in shade at noon on August 1 (summer) and February 1 (winter) per foot of overhang. To use the chart for a particular location, pinpoint where the latitude of the location intersects the heavy curved lines. The values beneath these points are the number of feet of wall in shade for each foot of overhang in the winter and summer.

Values for the latitude, 33.9 which is Columbia, are marked on Figure 3.

It is important to note the amount of shade cast by each foot of overhang in the winter, approximately .6 for Columbia. This value can be used to size the separation between the bottom of the overhang and the top of the window in order to provide for maximum solar gain during the winter.



For example, a two foot overhang in Columbia would permit a window to be placed within the wall area that is 1.2 to 7.2 feet below the overhang.

It should be noted that the different overhang lengths within the recommended range will perform differently. Longer overhangs will provide more shade than shorter overhangs, particularly in the spring and fall. The specific heating and cooling needs of the individual house should be considered in sizing the overhang within this range of lengths.

Sunspaces

A sunspace is a popular addition to any house. It can be used as a home heating system, a year-round garden or as extra living space. Sunlight passes through a sunspace's windows and warms the sunspace's interior. Generally, the interior surfaces include a concrete floor, brick wall, water-filled drums or some other form of storage mass. Some heat is absorbed and stored in this storage mass. When the sun sets and the sunspace's temperature drops, the storage mass slowly releases the stored heat. The heat not absorbed raises the air temperature inside the sunspace. As long as the sun shines this heat can be circulated into the house by natural convection or drawn in by a low power fan.

Five Passive Solar Elements

Sunspaces must include the following elements to be a complete passive solar heating system:

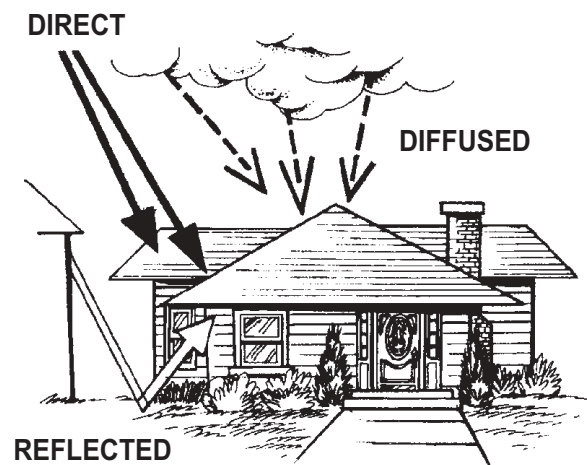
1. **Collector** – such as the double layer of greenhouse window glazing (glass or plastic).
2. **Absorber** – usually the surfaces of the walls, floors and/or waterfilled containers inside the sunspace.
3. **Storage mass** – normally the concrete, brick and/or water that retains heat.
4. **Distribution system** – the means of getting the heat into and around the house (for example, fans and natural convective flows).
5. **Control system (or heat regulation device)** – such as movable insulation used to prevent heat loss from the sunspace at night, roof

overhangs that block the summer sun, thermostats that activate fans, vents for summer ventilation, and doors and operable windows for heat transfer to adjoining rooms.

One of the more important questions to consider when designing a sunspace is how it will be attached to the house. One option is to have the sunspace separated from the house by an uninsulated brick, block or concrete wall. This wall absorbs and stores solar heat. Some heat subsequently moves through the wall over a period of several hours. The sunspace can also be separated from the house by an insulated masonry wall if there is another form of thermal storage in the sunspace. In either case, most of the heat delivery is by natural convection through windows, doors or vents.

Another option is to have oversized windows and sliding glass doors where the sunspace is attached to the house. The primary storage mass for this sunspace design would be a masonry floor. The masonry should be at least four inches thick (typically, concrete slab covered with ceramic tile or brick). The floor should be left uncarpeted, carpeting prevents heat absorption. A combination of these options may be the best approach.

Selecting sunspace glazing has become complicated in recent years due to the development of glass and plastic products that admit sunlight in a variety of ways. The conventional choice has been double-paned glass windows, or in very cold climates, triple-paned units. In addition to these options, manufacturers currently produce glazings with baked-in coatings.



Some of these glazings reduce heat loss, some increase the amount of sunlight and heat that can be admitted, some reduce heat gain and some reduce only certain types of light.

A basic rule when deciding between double-glazing and coated-glazing is to use ordinary double-paned glass if your sunspace is only going to be used during the day and is permitted to get cool in the evening. If you intend to spend time in your sunspace at night also, the higher quality glazings – those with special coatings – are a better choice.

The sunspace window, specially designed to easily transmit sunlight, becomes a problem when the sun sets. The loss of heat back through the glass may result in losses greater than the daytime solar gain. Movable insulation is one solution. Night insulation improves the sunspace's performance as a solar heat collector.

Results from monitoring homes indicate that well designed sunspaces can provide up to 60 percent of a home's heating requirements during the winter. The percentage depends on the square footage of the sunspace glazing, local climate, the heat requirement of the house and other design details of the sunspace/house combination.

Because your goal in the summer is to cool your house rather than heat it, your sunspace requires different maintenance at this time. Sunlight must be kept out of the sunspace and heat that accumulates must be vented. The same movable insulation used to prevent heat loss on winter nights can be used to prevent heat gain on summer days.

Exterior shades are more effective since they block the sun's heat before it enters the sunspace. If your sunspace has vertical windows, a carefully sized solid roof overhang will block some of the summer sun while still admitting sunlight in the winter. Retractable awnings or reflective shades are other choices. Deciduous trees or shrubs provide shade but must be placed carefully to avoid blocking winter sun. For venting heat, the sunspace may use an exhaust fan.

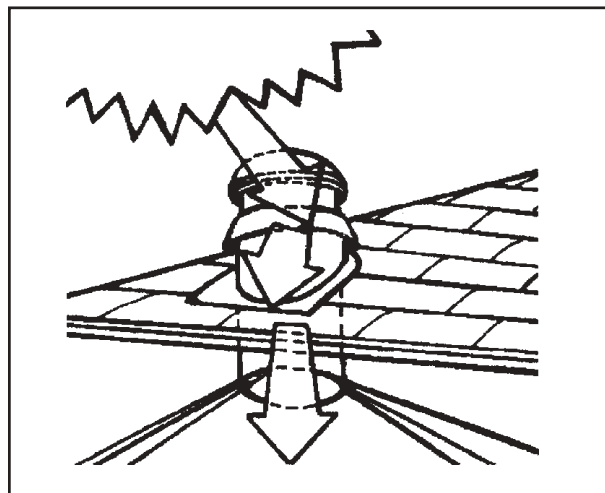
Intensive use of a sunspace for growing plants significantly decreases the area's heat output. Depending on the kind and number of plants grown, evaporation from leaves can cut your sunspace's heat gain in half. A general rule is to expect your sunspace's heat output to be reduced by the percentage of floor area the plants occupy.

Plants can have a positive effect. They can act as natural humidifiers, making sunspace gardening especially beneficial for dry climate regions.

Many plants cannot tolerate the high temperatures and temperature swings that occur in sunspaces designed for heating. Plants in sunspaces designed primarily for heat should be limited to a small number of plants that can tolerate the high temperatures of the sunspace.

Bright Idea: The Energy-saving Sun Pipe

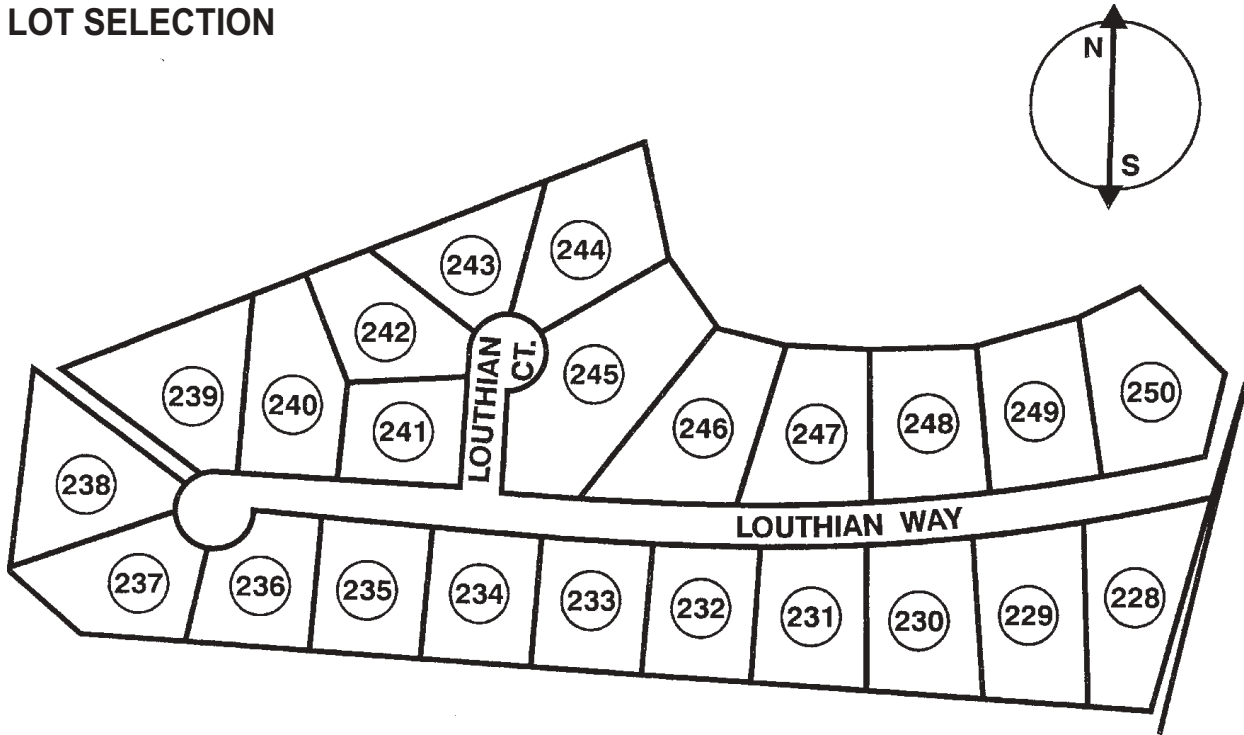
This 13-inch-diameter stainless steel tube, easily installed in the roof without sawing through joists or rafters, is a new, low-cost way of illuminating your home. It works (even on overcast days) by capturing and reflecting sunlight down the interior of the highly polished tube into a domed ceiling globe. The gadget provides natural light and costs nothing to operate. Unlike a skylight, it does not pour unwanted heat into a room in summer or lose heat in winter. It is available to homeowners for about \$400. For more information, visit www.sunpipe.com.



Design for Energy Efficiency

Complete this worksheet on your home selection and your ideas for energy efficiency.

LOT SELECTION



Study the orientation of the various lots in the neighborhood and mark your selection of a site for your home on the site plan. Draw in a box to represent how your home would sit on the lot. Note which way your home will face in reference to the sun. Your Lot Number is: _____.

Explain an energy-efficient consideration for your selection: _____

LANDSCAPING

On your chosen lot, indicate any trees you would plant with an X. What type of tree (evergreen or deciduous) would you plant? Why? _____

OVERHANGS

Would you use overhangs? If so, what length? On which windows? What other window treatments would you use? _____

YOUR BEST IDEAS FOR SAVING ENERGY

Describe any special features of your home that would help it be energy efficient. _____

SUNSPACES

Would you include a sunspace? Why or why not? Where would it be located? In the box draw a simple floor plan to show the layout of your home (label the rooms) with or without a sunspace.



Fuel Wise or Fuelish?

Preparation Time:

Easy-to-do

Moderate

Extensive

Grade:	9 – 12
Focus:	Choosing a car with the environment in mind
Subject:	Science, Social Studies, History, Math, Economics
Materials:	See below
Teaching Time:	One to two weeks
Vocabulary:	OPEC, compressed natural gas, propane, ethanol, biodiesel

Alternative Fuels

Excerpts from the
Energy Factbook: A Resource for South Carolina

What are alternative fuels?

The term “alternative fuel” is used to describe fuels other than gasoline that can be used to fuel our cars. In 1992, the U.S. Congress passed a law called the “Energy Policy Act.” This Act made it a law for governments and utilities to use alternative fuels made in the United States to power part of their vehicle fleets. The fuels that must be used are compressed natural gas, propane, electricity, ethanol or biodiesel.

Why are alternative fuels important?

The United States uses more oil than any other country in the world, and a little less than half of that oil comes from our country. The rest of it is imported from other countries – mostly countries in the Middle East. Our dependence on oil from other countries makes us very vulnerable, and puts our national security at risk.

In the 1970s, the Arab nations of the Organization of Petroleum Exporting Countries (OPEC) announced an “embargo” on exporting oil to the United States. This means that they decided to not sell us any more oil. They did this because they were angry that the United States supported Israel in the Arab-Israeli War. As a result of this, oil prices in the United States skyrocketed because there wasn’t enough supply. Gasoline was rationed, which means that you were only allowed to buy it on certain days. This had a severe effect on our economy and President Richard Nixon announced that the United States must attempt to use less oil.

Congress passed many laws in the 1970s to achieve this goal, and those laws received support from Presidents Gerald Ford and Jimmy Carter.

Learning Objectives

In this lesson students will:

- learn how world events affect supply and demand for petroleum;
- explore why it is important for South Carolinians to use alternative fuels; and
- make decisions pertinent to choosing a fuel-efficient car.

Learning Procedure

Students will choose a new car and determine the cost of operation for one year to include price, fuel, insurance, property taxes, title, tag and maintenance.

Materials

- “Alternative Fuels” from *The Energy Factbook: A Resource for South Carolina* by the S.C. Energy Office (provided)
- Current year Fuel Economy Guide from the U.S. Environmental Protection Agency (EPA) found at www.fueleconomy.gov/
- Internet access to gather various price quotes
- “Buying My First Car” Worksheets 1 and 2 (provided)

Some of these included new vehicle efficiency standards, and also the 55 mile-an-hour speed limit. This was passed because vehicles operate most efficiently at this speed. All these laws had a positive effect.

Oil prices rose again in 1992 following the Gulf War, and President George Bush championed the passage of the Energy Policy Act. This law was intended to drastically reduce our dependence on foreign oil by increasing the use of domestically-produced fuels in our government and utility provider fleets. Beginning in 1996, fleets were required to begin purchasing alternative fuel vehicles (AFVs). The percentage of AFVs was increased each year, and by 2001 75 percent of new vehicles purchased had to be AFVs.

In spite of this law, demand for oil continues to rise. By 2000, Americans were using roughly 19.5 million barrels of oil a day, with 58 percent of that coming from foreign countries. It is clear that we still have a lot of work to do in this area.

Such widespread use of oil has another effect besides oil dependence. Overuse of fossil fuels has helped cause significant air pollution throughout the United States. When most people think of air pollution, they think of Los Angeles, CA or Houston, TX.

Surprisingly, Charlotte, NC and Atlanta, GA, our neighbors to the north and south, have some of the highest pollution rates in the country. Even in South Carolina, air quality is threatened by emissions from gasoline. Fortunately, alternative fuels can help ease those problems as they burn more cleanly than gasoline.

The Alternative Fuels

Compressed Natural Gas (CNG) and Liquefied Natural Gas (LNG)

Natural gas is domestically produced and readily available in the United States. Natural gas is also clean burning and produces less pollutants than reformulated gasoline. Natural gas can either be

stored on board a vehicle in tanks as compressed natural gas (CNG) or cryogenically cooled to a liquid state – liquefied natural gas (LNG).

Natural gas is a mixture of hydrocarbons – mainly methane (CH₄) – and is produced either from gas wells or in conjunction with crude oil production. Natural gas is also used for heating and cooling homes, cooking, clothes drying and businesses.

Although one of the cleaner-burning alternative fuels, natural gas is not yet used very widely. The vehicles typically cost about \$3,500-\$5,000 more than a regular gas vehicle, and the refueling stations cost anywhere from \$400,000 for a “fast-fill” station that fuels a vehicle in just a few minutes to \$3,500 for an in-home compressor that fills a vehicle overnight.

Propane (Liquefied Propane Gas, LPG)

Propane or liquefied petroleum gas (LPG) is a popular alternative fuel choice. In fact, propane has been used widely for years in agricultural communities. Like natural gas, propane produces fewer vehicle emissions than reformulated gasoline. Propane is produced as a by-product of natural gas processing and crude oil refining.

Propane is a simple mixture of hydrocarbons, mainly propane/propylene (C₃S) and butane/butylene (C₄S). Propane is also a popular choice for home heating and outdoor cooking.

Propane vehicles also cost more than their gasoline counterparts. Fueling stations, however, are fairly inexpensive. More than 350,000 vehicles, mostly in fleets, are traveling the nation’s highways under propane power.

Electricity

Electricity can be used to power vehicles. Electric vehicles (EVs) store electricity in batteries. EV batteries have a limited storage capacity and must be replenished by plugging the vehicle into a recharging unit. The electricity for recharging the batteries comes from a special electrical outlet in the home or business or from distributed renewable sources such as solar or wind energy.

EVs are called “zero-emission vehicles” because they release no harmful emissions into the air.

The costs of “refueling” an EV are minimal, but an EV certified to run on the highway is very expensive. Although newer battery technology shows promising developments, most EVs have a range of only 50-100 miles before recharging is needed.

Ethanol (E-85)

E-85 is a blend of 85 percent ethanol and 15 percent gasoline. Ethanol is an alcohol-based fuel produced by fermenting and distilling starch crops that have been converted into simple sugars. Feedstocks for this fuel include corn, barley and wheat. Ethanol can also be produced from “cellulosic biomass” such as trees and grasses. Most ethanol used in the United States today is made from corn.

E-85 can be used in “flex-fuel vehicles.”

These vehicles can also run on pure gasoline.

These vehicles are very common in the United States today – many

auto manufacturers now offer them standard.

Unlike other AFVs, there is no additional cost for purchasing this vehicle. Because of this, and also because they can run on gasoline, they are a popular choice for fleet managers. Ethanol fuel, however, is more expensive than gasoline at the pump, but is better for the environment.

Biodiesel

Biodiesel is manufactured from vegetable oils or recycled restaurant greases. Biodiesel is safe, biodegradable, and reduces serious air pollutants such as particulates, carbon monoxide, hydrocarbons, and air toxins. Blends of 20 percent biodiesel with 80 percent petroleum diesel (B20) can be used in any diesel vehicle. It can also be used in its pure form (B100), but may require certain engine modifications to avoid maintenance and performance problems. French fry-fueled Fords may be in your future!

Alternative Fuel Use in South Carolina

The government offices of South Carolina began purchasing AFVs in 1996, as required by law. However, while the Energy Policy Act required that governments buy AFVs, it did not demand that they use any alternative fuel. Since some AFVs can run on either an alternative fuel or regular gasoline, we have many AFVs and not many refueling sites. This is partly because of the high cost of installing the equipment.

However, this is changing. Since 2000, South Carolina has developed three new AFV refueling sites with plans to develop more.

What kind of fuel do we use?

In 2002, our state Office of Fleet Management surveyed all government groups in the state to determine how many and what kind of AFVs they had. They also surveyed fuel providers

to find out where our AFVs could go to refuel as state employees drive these vehicles to go about the state’s business. This survey helped us discover that while we have about 2,500 AFVs operating in government fleets in South Carolina, we don’t have much alternative fuel to put in them. This survey, however, also helped us plan where to put alternative fuel stations in the future.

- **Ethanol:** Ninety-three percent of the AFVs operating in S.C. government fleets (about 2,300) are flex-fuel vehicles. Since these vehicles can run on either gasoline or E-85, many continue to be operated on gasoline. In 2002, two stations that dispense ethanol opened in South Carolina.

United Energy Distributors, Inc., a private fuel supplier in Aiken, South Carolina, opened the first public multi-alternative fuel station in the country in October 2001. It sells E-85, in



addition to propane and biodiesel. Anyone can buy fuel at this facility, making it the only publicly-accessible AFV refueling site in the state.

The S.C. Department of Health and Environmental Control opened an E-85 refueling site in Columbia in April 2002. This facility serves only vehicles owned by federal, state or local governments, not the public. There are over 600 flex-fuel vehicles in government fleets in Columbia, and this is the first time they have had access to E-85.

Hopefully, more ethanol facilities will open soon across the state. Many private citizens own flex-fuel vehicles, and they will be able to take advantage of using this alternative fuel as well.

- **Biodiesel:** It's hard to count the number of vehicles using biodiesel, because any diesel vehicle can use it. We do know, however, that our state fleet and some federal fleets in our area have purchased biodiesel in bulk to use in their vehicles. In addition, the South Carolina Soybean Board is working to study whether a private company in Aiken could start a biodiesel production facility in South Carolina. Right now, we purchase our biodiesel from Kentucky, which makes it more expensive for us to use.
- **CNG:** In 2000, the Clean Cities Coalition in Columbia, South Carolina worked closely with the Central Midlands Board of Directors as they made decisions regarding the fate of Columbia's bus fleet. Thanks in part to their efforts, the Board decided to purchase seven new compressed natural gas (CNG) transit buses when they replace S.C. Electric & Gas' (SCE&G) aging bus fleet. These buses are expected to reduce nitrogen dioxide and hydrocarbon emissions by 6,296 pounds per year over a ten-year period, which will result in a cleaner Capital City. The Coalition and the

S.C. Energy Office are also working to expand the capacity of Columbia's only CNG refueling station, and to encourage other agencies to purchase CNG vehicles. Several new city buses will be fueled by natural gas as a result of this effort. In addition to the new buses, the state fleet in Columbia owns 70 CNG vehicles.

Local governments and utility companies in South Carolina own some CNG vehicles as well. In addition to the "fast-fill" CNG stations in Columbia and York County, there are "slow-fill" stations in the cities of Rock Hill and Clemson, and Greenville County.

- **Propane:** There is more propane refueling infrastructure in the state than any of the other fuels, because many propane companies use the fuel in their vehicles. There are, however, only 54 propane vehicles in the state fleet, and only one station in South Carolina that accepts the state's credit card. That is the United Energy facility in Aiken.

Where do we go from here?

Alternative fuel use is very important for our state and our country because of our dependence on imported oil and our national air quality problems. There are many organizations in our state that want to help increase the types and amount of alternative fuel that we use, and the Palmetto State Clean Fuels Coalition is trying to organize all the groups and their efforts. This local group is part of a national effort called "Clean Cities" which is coordinated by the U.S. Department of Energy.

The Palmetto State Clean Fuels Coalition is committed to working towards developing stronger networks of alternative fuel users in the state. It is reaching out to all existing organizations and programs that show a similar interest in improving our nation's energy security through less dependence on foreign oil and reducing emissions of ozone, carbon monoxide and particulate matters associated with motor vehicle usage.

Buying My First Car

Your generous Uncle Bill has just offered you \$5,000 toward the purchase of your first car. The money, however, comes with some strings attached. In order to get the money, you must first prove that you are mature enough to handle the responsibilities associated with car ownership including financing, insurance, maintenance and everyday operating expenses.

STEP ONE: Choose three different cars you would like to purchase. Choose one new car, one used car and one alternative fuel vehicle. Complete "Buying My First Car Worksheet 1" which will compare the costs of these car models.

STEP TWO: Once you have selected the cars of your choice, check out the financing options that are open to teenagers. Are you going to pay cash for the car, make a down payment and monthly payments, or buy one for more than the \$5,000 and finance the rest? Research different lending institutions and record their interest rates the

worksheet. You must also research the tax situation.

STEP THREE: Insurance will be the next item of major concern. It is assumed that you will be paying for your own insurance. Look at three insurance companies and compare the prices of the policies based on your age, gender, academic achievements, prior convictions of offenses, etc. The type of car selected will also affect the insurance coverage. Complete the insurance section on the worksheet.

STEP FOUR: Determine annual fuel cost based on an average of 10,000 miles traveled annually.

STEP FIVE: Complete the "Buying My First Car Worksheet 2" by compiling the information gathered from your research and creating a spreadsheet. From this spreadsheet create a graph, which will help you compare and make a wise automotive choice.

Buying My First Car Worksheet 1

	New Car	Used Car	Alternative Fuel Car
Car Model			
Base Price			
Insurance Costs (Yearly)			
Driver's Training Costs			
Financing Costs (Yearly)			
Maintenance Costs (Yearly)			
Registration Costs			
Tax			
Title			
License Tag			
GRAND TOTAL			

Buying My First Car Worksheet 2

1. After you have decided on the car to purchase and all costs have been recorded on Worksheet 1, design a spreadsheet with all the costs listed from Worksheet 1. Create a graph with this information.

2. Do you think that purchasing a 5-year old car is a better deal if you include maintenance costs in the overall price?

3. What are the advantages of purchasing a used car versus a new car? What are the disadvantages?

4. What surprised you most about your "car buying" experience?

Radioactive Waste Disposal

Preparation Time:

Easy-to-do

Moderate

Extensive

Grade:	9 – 12
Focus:	Exploring the need for safe radioactive waste disposal
Subject:	Science, Social Studies
Materials:	“Nuclear Energy – Benefits and Problems” handout included with this lesson
Teaching Time:	One class period. This lesson should be used in conjunction with the lesson “Nuclear Power in Our State.”
Vocabulary:	Radioactive, transuranic waste, high level radioactive waste, deep geologic repositories, near surface waste disposal.

and nuclear weapons also is radioactive waste. Unless they are solidified or absorbed, these take the form of a liquid or sludge.

In the United States, radioactive materials are divided into two groups for purposes of permanent disposal. One group consists of wastes that can be disposed of in the upper 100 feet of the earth’s surface in a disposal facility like the one in Barnwell County, South Carolina. This is called “near-surface” disposal. The other group consists of wastes that require a higher degree of isolation in a “deep geologic repository.”

Deep Geologic Disposal in the U.S.

The only deep geologic repository currently operating is the federal Waste Isolation Pilot Project (WIPP) located near Carlsbad, New Mexico. The WIPP site accepts long-lived radioactive waste, known as “transuranic waste,” from the Savannah River Site in South Carolina and other U.S. Department of Energy facilities.

Another deep geologic repository under development, the Yucca Mountain site in southeast Nevada, will accept spent nuclear fuel from commercial power plants. The Yucca Mountain site also will accept “high-level” radioactive waste that is now in storage at Department of Energy facilities. Included in this will be plutonium wastes and other high-level waste from the Savannah River and other federal sites. Until the Yucca Mountain site begins accepting waste, most spent fuel from nuclear power plants will continue to be stored at the 110 nuclear reactor facilities across the nation in water-filled fuel pools.

The Barnwell Near-Surface Disposal Facility

The Federal government requires that near-surface radioactive waste disposal facilities be owned by the federal government or by state governments. This is because these facilities will require monitoring, custodial care and restricted

Learning Objectives

In this lesson students will:

- explore the need for safe disposal of radioactive waste;
- see why South Carolina plays such a vital role in radioactive waste disposal; and
- learn what South Carolina’s responsibilities will be in the future.

Introduction

Radioactive waste comes in many forms. Familiar objects that we encounter on a daily basis can be considered radioactive waste if they become radioactively contaminated. These include uniforms, gloves, construction materials and tools. Some radioactive waste is less familiar. Filter material used for capturing radioactive elements in the cooling water of nuclear power plants is a common form of radioactive waste. The processed residue from the manufacture of nuclear materials

access long into the future. The near-surface disposal facility in Barnwell County is owned by the State Budget and Control Board and is operated under a lease agreement by a private company. There are currently only two other such disposal facilities for commercially-generated radioactive waste in operation in the United States. One of these is located in eastern Washington State and the other west of Salt Lake City, Utah.

The facility in Barnwell County was opened in 1971 and has disposed of approximately 27 million cubic feet of waste over an area of 100 acres. Waste is placed in large, specially-built trenches. Each trench has a gently sloped floor to prevent accumulation of water during the period the trench is open. A layer of gravel separates the waste packages from any ground water that may intrude during waste emplacement operations. Once filled, each trench is capped with a sandy clay material in order to channel surface water away from the trench area. Upon site closure, a permanent multi-layer cap consisting of both natural and synthetic materials will be placed over the entire site as further protection against the intrusion of surface water into the trenches.

As with the other similar facilities, there are strict regulatory limits on the form of the wastes that can be accepted. Wastes cannot include free-standing or unabsorbed liquids. They cannot include chemically hazardous materials. Waste packages must be generally free of air pockets that could cause the trench caps to sink.

Federal and state regulations require an environmental monitoring program to detect any radioactivity outside the trenches. The monitoring program must continue for at least 100 years after the site is closed.

Future of the Barnwell Site

In late 1999, a Governor's task force recommended that a portion of the remaining three million cubic feet of disposal capacity at the Barnwell disposal facility be saved for use by nuclear power plants and other industries located within the state. These seven nuclear plants will require a large amount of disposal space in future decades. The task force was concerned that if South Carolina did not take action, the Barnwell site would be filled with waste from other states long before our own industries needed it.

Following a recommendation by the task force, the South Carolina General Assembly in 2000 joined a three-state alliance with Connecticut and New Jersey called the Atlantic Interstate Low-Level Radioactive Waste Compact. Because the Atlantic Compact had been authorized by the U.S. Congress to limit access to its regional disposal facility to the member states only, this provided the legal authority the state needed to keep out waste from other regions.

The 2000 law also phased out acceptance of radioactive waste from across the nation. By 2009, the Barnwell site may not accept any waste from outside the three-state region.

Nuclear Energy: Benefits and Problems

The following is a list of benefits and problems associated with nuclear powerplants. A key word or phrase in each item is printed in bold face. Read the list and put a (B) in the blank if it is a benefit, a (P) if it is a problem.

- | | |
|--|---|
| _____ Less need for mining and TRANSPORT of fuel. | _____ Reactors produce LESS WASTE than fossil fuel plants do. |
| _____ No POLLUTANTS from burning fuel. | _____ Higher COST TO BUILD . |
| _____ Less reliance on IMPORTED FUEL . | _____ Large amounts of PLUTONIUM could lead to spread of nuclear weapons. |
| _____ Could be targets for TERRORISTS . | _____ Possibility of RADIATION ESCAPING . |
| _____ The fuel COST of a nuclear power-plant is lower than fuel costs for fossil fuel plants. | _____ RADIOACTIVE WASTE must be handled and disposed of safely for thousands of years. |

Now that you have identified the problem areas, look at the arguments below. Each one concerns a problem area and offers arguments for (PRO) and against (CON) expansion of nuclear energy. Complete the arguments by inserting a KEY WORD (in capitals above) into the blanks above for each problem area.

PRO: The _____ is made into a type of glass or ceramic, put into special containers, and stored in places like salt beds that have been undisturbed for millions of years.

CON: It takes thousands of years for the _____ to lose its radioactive properties. We cannot ensure safe disposal for thousands of years and future societies may be hurt.

PRO: In more than _____ years of commercial nuclear powerplant operation, no one has suffered any ill effects brought on by _____.

CON: There's always a chance that an accident or mechanical malfunction could present the danger of _____.

PRO: Regulations and safeguards can be strictly enforced to keep the _____ out of the hands of terrorists. This radioactive waste is usually sealed in unbreakable capsules right after the fuel processing.

CON: Just 10 pounds of radioactive _____ is enough to make an atom bomb.



It takes thousands of years for radioactive waste to lose its radioactive particles.