FLORIDA SOLAR ENERGY CENTER®

Renewable Energy Activities for Middle Grades

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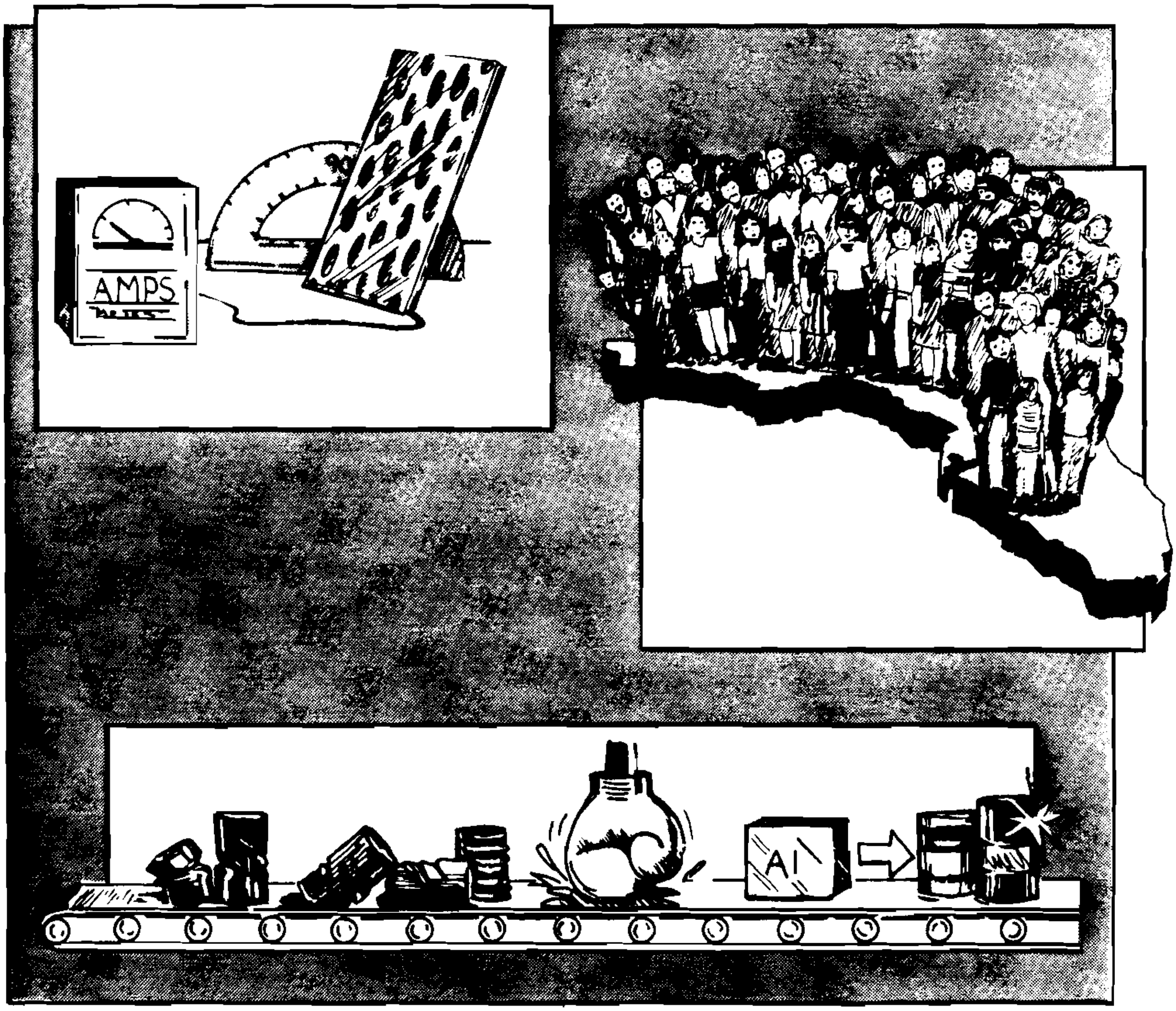
Renewable Energy Activities for Middle Grades



FSEC-EP-3-90

Introduction

The Florida Solar Energy Center (FSEC) is a research and education arm of the State University System hosted by the University of Central Florida. The Florida legislature established FSEC in 1974 to conduct research in alternative energy technologies, to ensure the quality of solar energy equipment sold in Florida, and to educate people about renewable energy technology.

One method of disseminating research results has been through teacher education programs and the development of instructional materials. FSEC-developed materials are designed to teach science and social studies research methods and/or process skills. The units have been field-tested and correlated with student performance standards and state curriculum frameworks.

This package of units has been taken from the **Florida Middle School Energy Education Project** (FMSEEP) that was developed for the Governor's Energy Office with the active involvement of teachers, supervisors and utilities. Copies of all the FMSEEP units are available from FSEC upon request. A student guide for **Energy Research Projects** and an **Energy Note** series provides detailed information about renewable energy technologies and energy conservation strategies. Contact us for a publications list.

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Your comments and suggestions are always welcome.

David E. LaHart, Ph.D.
Cape Canaveral, FL
May 1990

I Growing Fuels

Green plants capture energy from sunlight by the process of photosynthesis. But plants are not very efficient. They convert less than 1% of the available solar energy to sugar and starch, yet this tiny amount supports life on Earth. The energy in plant sugar and starch, called ***biomass***, can be used as a fuel source.

Biomass includes wood, leaves, crop residues, and even garbage. Biomass can be burned directly, converted into liquid fuels such as alcohol, or made into methane gas, which is used like natural gas. Because Florida has such a long growing season, people may be able to produce special crops to be used as biomass fuel.

A pound of dry plant tissue can produce as much as 7,500 Btus of heat, a little more than half of the heat available from a pound of coal. A ton of dry biomass can be processed to yield 1.25 barrels of oil, 1,200 cubic feet of methane, and 750 pounds of solid material about equal to coal in heat value.

Of course people don't want to harvest every scrap of plant material for fuel. But they could use materials that are now being wasted. Crops can be grown especially for fuel, and the energy in our garbage and sewage could also be used.

Dry Biomass in One Year From One Acre in Florida

Corn	6	tons
Eucalyptus trees	8-25	tons
Sugar cane	12-50	tons
Sorghum	8-30	tons
Algae	15-30	tons
Sunflower	10-20	tons
Water hyacinths in sewage water	146-292	tons

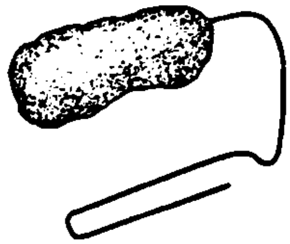
There are no large scale energy farms in Florida, but many small demonstration projects have been working for years. They have shown that drying biomass is expensive in terms of money and energy. So far, energy from fossil fuels is cheaper than energy from biomass. But as fossil fuels become more expensive, people may use more biomass. In Florida, about 5% of our total energy comes from biomass.

In this activity, you will build a device to measure heat energy and then measure the heat value of some common materials.

Name ____________ **Class** ____________ **Date** ____________

Objective:
To build and use a simple calorimeter

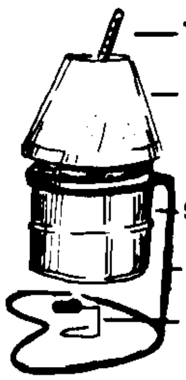
Materials:
Empty tin can (soup can is fine)
Paper clips
Styrofoam cup
Matches
Ring stand or wire coat hanger
Metric measurer for 100 ml
Celsius thermometer
Metric balance for weighing
Peanuts, other kinds of biomass fuels as directed


Paper clip fuel burner

Procedure:
1. Carefully measure and record the weight of a peanut.

2. As shown in the illustration, make a stand from a paper clip and poke the raised end of the clip into the peanut.

3. Bend a coat hanger to make a holder for the tin can like the one in the illustration. **Be careful.** The stand will have to hold some weight. Use two coat hangers if you need to.



4. Add exactly 100 milliliters of water to the tin can and cover it with the styrofoam cup.

5. Poke the thermometer through the styrofoam cup so that it touches the water but not the bottom of the can. Record the temperature of the water in the chart.

6. Put the peanut (fuel) under the tin can so that it is near but not touching the can. **Be careful. You will now ignite the peanut. Keep your fingers clear of the flame.**

7. Remove the peanut and stand, ignite the nut, and carefully but quickly put it back under the can. Burn the peanut and record the temperature of the water.

8. Weigh the unburned portion of the peanut. Subtract this weight from the original weight of the peanut. The difference is the weight of the part that burned.

Data Table		
Mass of fuel at start	______	g.
Mass of fuel after burning	(-) ______	g.
Change in fuel mass	______	g.
Highest water temp (T_F)	______	°C
Lowest water temp (T_S)	(-) ______	°C
Change in temp (ΔT)	______	°C
Volume of water	______	ml
Calories = volume of water x ΔT °C	______	

9. Calculate the caloric value of your peanut. The grams of water (100 milliliters = 100 grams) multiplied by the change in temperature (in degrees Celsius) equals calories.

$$\Delta T(\quad) \times 100 = \text{calories}$$

10. Now calculate the calories per gram for your peanut (the part that burned). Divide the total number of calories by the number of grams that were burned.

Conclusion:
Write a paragraph describing your results. Do peanuts have a lot of calories per gram?

More:
- Repeat the experiment with other kinds of fuels.
- What kinds of wood produce the most heat per gram?

Review for you:
Q1. How is the energy value of food determined?
Q2. What is the pathway of energy used to get the peanut from the ground to you?
Q3. Diagram the food chain that ends with you eating a peanut.

Think about this:
Q4. Your calorimeter did not catch all the heat from the burning peanut. Some heat escaped into the surroundings. What improvements can you suggest for your calorimeter?
Q5. How would you determine the energy value of a wet food like lettuce?
Q6. Why are foods that are rich in fats called concentrated energy?
Q7. Does candy give you energy? Explain.

2 It's Blowing In The Wind

Hot air rises. This simple observation explains how winds originate. Consider popcorn. When a kernel pops, the piece of corn weighs about the same, but it takes up a lot more room. Each cubic centimeter of popped corn weighs less than a cubic centimeter of unpopped corn. As the corn pops, the heavy unpopped kernels remain on the bottom of the pan, and the popped kernels rise above them. Solar energy has the same effect on the earth's air. The sun heats the air, the warm air rises and the cooler air sinks to take its place. This air motion is wind.

About 2% of the solar energy that falls on the earth is converted to wind energy. At any given moment, half of the earth's atmosphere is exposed to the sun, and half is in shadow. This uneven heating and cooling creates wind. Wind can be used to generate electricity, but only if the wind is over ten miles per hour.

Wind power is a renewable energy resource that can provide clean, nonpolluting energy where wind is abundant and available on a regular basis. Unfortunately, the winds in Florida are usually not steady or strong enough to generate electricity. A wind generator that is two meters in diameter, 30% efficient, and ten meters from the ground would produce only about 80 watts of electricity in Key West. How much wind energy is available where you live? In this activity you will measure wind energy.

Table 1. Average Wind Speed (MPH) for Some Florida Cities

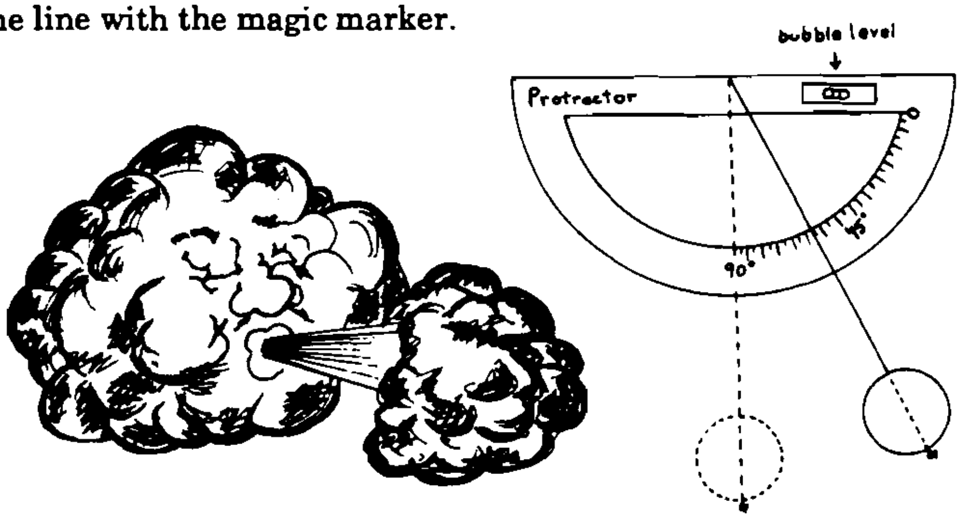
Station	10 Meters High	50 Meters High
Avon Park	5.4	6.9
Cape Kennedy	7.6	9.4
Daytona Beach	8.9	11.4
Ft. Myers	8.7	11.0
Jacksonville	7.6	9.6
Key West	11.6	14.8
Miami	9.8	12.5
Orlando	9.4	11.9
Panama City	8.3	10.3
Pensacola	8.1	10.1
Tallahassee	6.8	8.3
Tampa	8.7	11.0
West Palm	10.1	12.8

Name ______________________________ **Class** ______________________ **Date** ______________

Objective:
To build a device to measure wind speeds

Materials:
Ping pong ball
Fishing line, 30 cm long (6 - 10 lb. test is OK)
Large protractor
Bubble level (from a hardware store or made from a clear straw)
Glue
Needle (long enough to go through the ping pong ball)
Magic marker (red or blue is best)

Procedure:
1. Thread the needle with the fishing line and push the needle through the center of the ping pong ball. Tie a knot on one end of the line. Pull the line through the ball until the knot is just barely outside the ball. Glue the knot to the ball.
2. Glue the bubble level on the protractor, parallel with the straight edge.
3. Glue the other end of the line to the center of the protractor's straight edge.
4. Color the line with the magic marker.



5. Holding the protractor so that the bubble is centered, observe the angle the ping pong ball is deflected by the wind.
6. Record the location and the angle of deflection in several places around the school grounds or at home. Measure one location that is as high as you can safely go. Measure another location that is away from buildings. Measure another that is near the corner of a building.
7. Using the wind speed chart, calculate the wind speeds at each location. Record your observations in the chart.

Location	Height (estimate)	Angle of Deflection	Wind Speed (estimate)
a. ______			
b. ______			
c. ______			
d. ______			
e. ______			
f.			

Wind Speed Chart

Angle	Miles per Hour
90	.0
85	5.8
80	8.2
75	10.1
70	11.8
65	13.4
60	14.9
55	16.4
50	18.0
45	19.6
40	21.4
35	23.4
30	25.8
25	28.7
20	32.5

Conclusion:
Write a paragraph describing the wind speeds you measured during your survey. Did any places have enough wind energy to produce electricity?

Review for you:

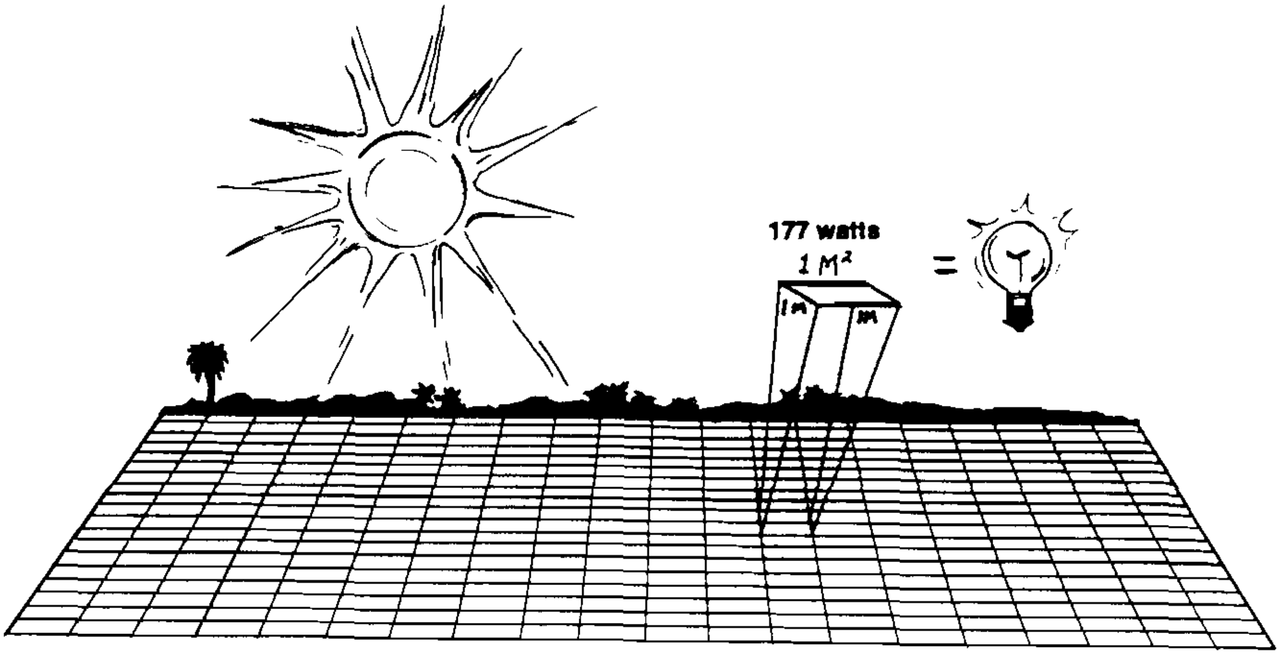
Q1. What is the difference between the wind speed at ground levels and the wind speed at higher locations?
Q2. Is the wind speed faster near buildings or out in the open?
Q3. Is there a steady wind all day at your school? Every day?
Q4. Did you find any good locations for a wind-powered electric generator?
Q5. Why is wind power considered a form of solar energy?

Think about this:

Q6. What are the advantages and disadvantages of using wind power to generate electricity in Florida?
Q7. Why is there usually more wind in the afternoons than early in the mornings?
Q8. Wind generators are not very efficient. Use your library to find out how scientists are trying to improve their efficiency.

3 Whew! That Sun Is Hot!

How much energy is there in sunlight? About 1.36 kilowatts per square meter (130 watts per square foot) falls on the upper atmosphere. About a third of this is reflected into space. How much sunlight actually reaches the ground depends on the latitude, season, and local weather. In the U.S., the average sunlight reaching the earth is 177 watts per square meter per day. This means that if you collected all the energy that fell on one square meter, it would provide enough power to operate one 150-watt light bulb. In 24 hours, one square meter receives a little more than 4 kilowatt-hours, or 3770 kilocalories of energy. The Sunshine State averages 4.5 kilowatt-hours (about 3900 Kcal) per square meter per day.



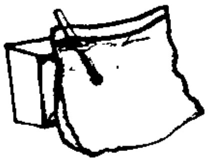
Sunlight travels through air, clear glass and plastic. When it strikes other materials, some is reflected and some is absorbed. The absorbed light energy changes into heat. Remember how hot a car parked in the sun can get!

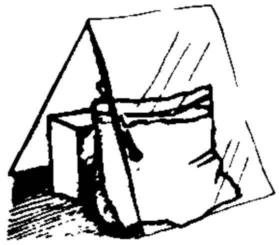
Different materials absorb different amounts of this solar heat. Dark colors absorb more than light or silver colors. Insulators reduce the amount of heat materials absorb. In this activity you will measure how color and insulation affect heat gain.

Name ______________________ Class ________________ Date __________

Objective:
To determine how a black base and insulation influence the rate of heat gain in a solar collector

Materials:
4 zip-able plastic bags, gallon sized
Metric measurer for 2 liters
4 Celsius thermometers
4 small props (to support the corner of the bag where the thermometer sticks out)
2 black pieces of paper
Insulation for the base of one bag (corrugated cardboard)
Sun shield for one bag (cardboard, an umbrella, or a shady place)
Water
Clock or watch
Clear, sunny day





Procedure:
1. Add exactly 2 liters of water to each bag.
2. Insert a thermometer with its bulb in the water and the other end sticking out one corner. Seal the bags the best you can. If the thermometer is small enough to fit, you may seal it in the bag.
3. Select a site where the bags will receive the same amount of sunlight (except for the shielded bag).
4. As you put down each bag, prop up the thermometer corner so the water doesn't spill. Make sure you can read the thermometer without taking it out of the bag.
5. Label the bags - A, B, C, and D.
6. Put down bag A and shade it from direct sunlight.
7. Put down bag B in the sunlight.
8. Put down a black sheet of paper and place bag C on it.
9. Put down the cardboard base (or other thick insulation), black paper, and bag D.
10. For each bag, record the starting temperature and the temperature at each 5-minute interval for at least 20 minutes. Record your data here or in your lab book.

	Start Temp.	5 min.	10 min.	15 min.	20 min.	25 min.
Bag A (shaded)	______	______	______	______	______	______
Bag B (full sun)	______	______	______	______	______	______
Bag C (black paper, full sun)	______	______	______	______	______	______
Bag D (black paper, full sun, insulated)	______	______	______	______	______	______

11. Calculate the heat gain for all collectors (bags). Heat gain equals the final temperature minus the starting temperature, multiplied by 2. This heat gain is in kilocalories.

	final temp	-	start temp	=	________	x 2	
Bag A	________	-	________	=	________	2	______________ Kcal heat gain
Bag B	________	-	________	=	________	2	______________ Kcal heat gain
Bag C	________	-	________	=	________	2	______________ Kcal heat gain
Bag D	________	-	________	=	________	2	______________ Kcal heat gain

Conclusion:
Make a graph of your data and describe the results of your tests.

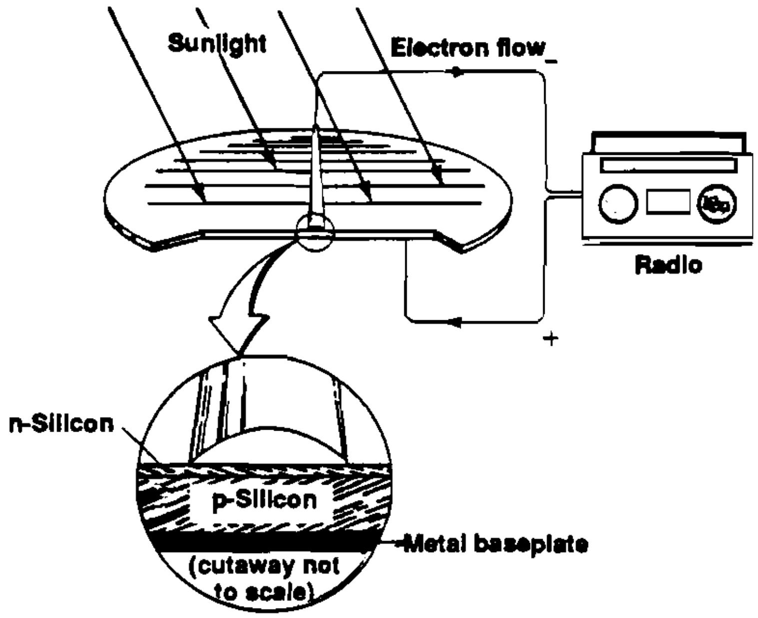
More:
- What would happen if you put only 1 liter of water in each bag? 3 liters? Which would gain the most heat?
- What would happen if you placed your bag of water on aluminum foil painted black (or white or dark green or red or unpainted)?
- Design a totally new experiment for your four plastic bags of water! Do it!!

Review for you:
Q1. Bag A gained heat from the environment. What was the source of this heat? ________
Q2. Bag B gained heat from the environment and from direct sunlight. How much heat did bag B gain from direct sunlight? (Subtract the heat gain for bag A from the heat gain for bag B.)
Q3. Without the black background, how much heat would bags C and D have gained?
Q4. How much more heat did the black base help the water gain? (Subtract the heat gain for bag B from the heat gain for bag C.
Q5. How much more heat was gained because of the insulation? (Subtract the heat gain for bag C from the heat gain for bag D.)
Q6. Which bag gained heat at the fastest rate? Explain.

Think about this:
Q7. If you were out camping, how could you use the sun to help you take a warm shower?
Q8. What do you think a good solar water heater should look like? Make a labeled drawing of it.
Q9. What are the seasonal effects on the amount of light energy reaching the Earth? Would a solar collector work the same all year?

4 Making Electricity from Sunlight

Solar electric, or photovoltaic (PV), cells have been called the ultimate source of electrical energy. Without turbines, generators, or any moving parts, solar cells simply and silently produce electricity. This illustration shows how solar cells convert light energy to electricity. When light hits the cell, it releases electrons. The electrons move across a grid in the cell and are taken off by a wire. This flow of electrons is electricity.



Photovoltaic cells are expensive ($5 to $8 per watt). For this reason, scientists are trying to reduce the cost of making the cells. For many applications, PV technology is already cost-effective, when the power demand is low or the location is far from existing power lines. For example, you may have a solar-powered calculator or watch, an item that only needs a small amount of electric energy. The Coast Guard uses photovoltaic cells to charge batteries that operate lights in boating channels. NASA uses them to power satellites.

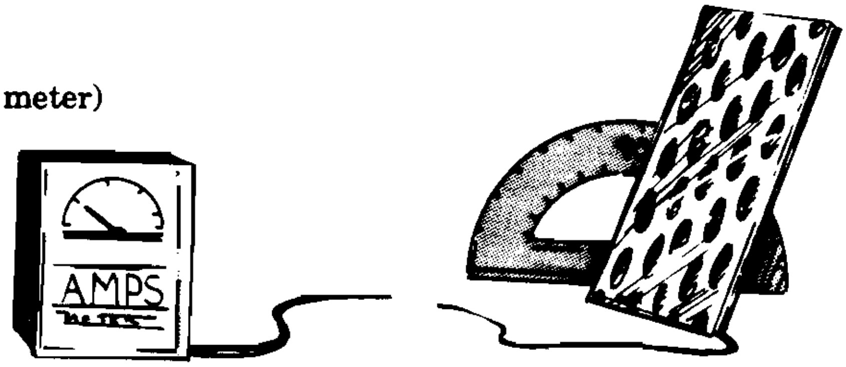
Scientists are also trying to increase PV cells' efficiency. Single crystal cells convert 8% to 10% of the solar radiation to electricity, polycrystalline cells convert 6% to 8%, and thin film, or amorphous, cells convert 3% to 4% of the solar energy that is available. There is a lot of room for improvement in cell technology. But remember, green plants have been around for millions of years and they convert less than 1% of the available energy!

One possible way to increase the efficiency of PV cells is to reflect additional sunlight on to them. This activity will show you how much more electrical energy can be produced when reflectors are used.

Name ____________________ **Class** ________________ **Date** __________

Objective:
To measure the effectiveness of reflectors in increasing the energy output of a photovoltaic module

Materials:
Minimodule (3 to 12 volts)
Multitester meter (or volt-amp meter)
Flashlight bulb
Small DC motor
Protractor
Graph paper
Laboratory notebook
Aluminum foil reflectors



Procedure:
1. Become familiar with the multitester by measuring the voltage output of your PV module. Your results should be close to the voltage identified by the manufacturer (3-12 volts). Check with your teacher if you need help.
2. Point the module at the sun and measure the amount of current (amps) the module produces when it is lying on a flat surface. Identify the correct scale on the multitester and observe the current increases when you slowly elevate the module until it is ***normal*** (perpendicular) to the sun's rays.
3. The amount of current a PV module produces depends on the the amount of sunlight it receives. Measure and record the current output of the module when it is flat (0°) and at each successive 10° interval until your module is at 90°. Use the protractor to measure the angles.
4. Attach reflectors along both sides of the module, and repeat the measurements you made in step 3. (If reflectors are not included with the minimodule, you can make them by gluing aluminum foil on cardboard).

	Current (amps)	
Degree	Without Reflectors	With Reflectors
0		
10		
20		
30		
40		
50		
60		
70		
80		
90		

5. Make a graph of the data you collected. Put ***current*** produced on the x axis and the ***tilt of the module*** on the y axis.
6. How much difference did the reflectors make? Calculate the increase in efficiency at 20°, 30°, 40° and 50°. (Hint - Divide the amount of current with the reflectors by the amount of current without the reflectors.)

Conclusion:
Describe the effectiveness of sunlight reflectors on the current production of photovoltaic modules.

More:
- Repeat the experiment using different kinds of reflective materials.
- Does the size of the reflector make a big difference? Design an experiment that will test the efficiency of variously sized reflectors on current output.
- How will the reflectors affect the power output early in the morning and late in the afternoon?

Review for you:
Q1. What type of photovoltaic module is the most efficient?

Q2. What are the two units of electricity that can be easily measured with a multitester?

Q3. Why are scientists experimenting with different kinds of reflective materials instead of just making the modules larger?

Q4. When referring to photovoltaic systems, what does the term "normal" mean?

Q5. What are some uses of PV systems that are cost-effective today?

Think about this:
Q6. Many scientists are trying to increase the efficiency of PV modules. Visit the library and develop a report on recent advances in PV technology.

Q7. Photovoltaic systems are cost-effective ***today*** when the power demand is low and the location is far away from existing power lines. Visit the library and investigate the use of PV systems for vaccine refrigeration, water pumping, lighting and telecommunications.

Q8. Why are solar cells important to NASA? Investigate NASA's role in developing photovoltaics.

5 Muscle Power! It Costs.

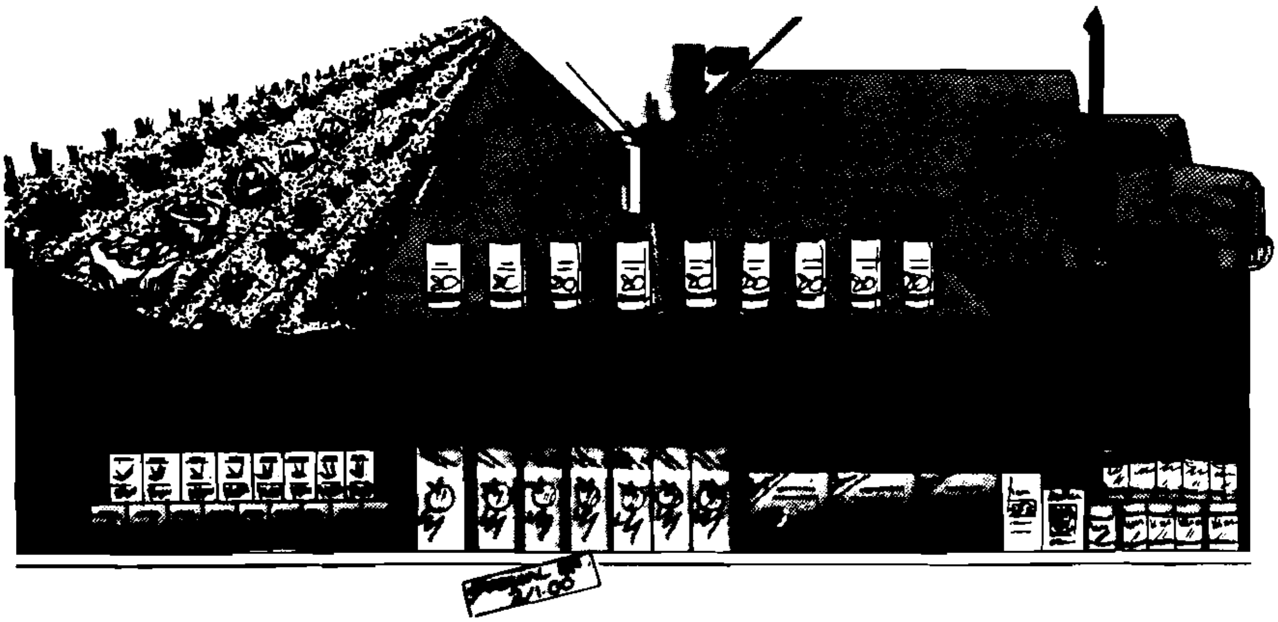
Your muscle power comes from the foods you eat. The foods get their energy from sunlight. But most people don't wander in the wilderness, munching plants and catching small animals to eat. Most folks get their food at a grocery store.

How does the energy needed to get certain food products to your home compare with the energy in the food? For example, the energy needed to transport orange juice from Brazil to Florida may be more than the energy you get from drinking the orange juice. Table 1 shows the amount of energy used to produce some common foods. These numbers only include the energy used during these steps:

	Energy needed for
Growing	planting, cultivating, pesticides, fertilizers
Harvesting	mechanically collecting the crop
Processing	washing, sorting, slicing and packaging
Transporting	moving from the farm to warehouse to market
Storing	keeping the crop cool and looking fresh
Marketing	lighting and refrigerating

The energy figures in Table 1 do not include the energy required to get the food from the market or to prepare it. The energy costs of the containers and packaging materials are not included either; if they were, the energy costs of the food would be much higher.

In this activity, you will calculate the ratio of the energy it takes to produce certain foods to the actual energy value of that food. You will learn that some foods are less "energy intensive" than others.



Name ______________________ Class ________________ Date __________

Objective:
To compare the energy costs with the caloric content of food items

Materials:
Paper and pencil
Calculator (optional but helpful)

Table 1. Comparison of "Energy to Produce" with "Energy in Food"

Food	Energy to Produce (Calories)	Energy in Food (Calories)	Energy Ratio
Wheat bread, 1 slice @ 18 slices/lb.	115	61	____to____
Milk, 8 oz. (1 cup)	848	158	____to____
Cheese, 3 oz.	2229	339	____to____
Grain-fed beef, 3 oz.	1997	246	____to____
Grass-fed beef, 3 oz.	1390	222	____to____
Lunch meat, 3 oz.	1545	258	____to____
Chicken, 3 oz.	897	141	____to____
Tuna, 3 oz.	2404	245	____to____
Tomatoes (fresh), 1/2 cup	356	23	____to____
Tomatoes (canned), 1/2 cup	583	24	____to____
Potatoes (fresh), 1/3 lb.	238	108	____to____
Potatoes (frozen hashbrowns),1/3 lb.	1247	339	____to____
Potato chips, 1/3 lb.	1855	859	____to____
Potatoes (canned), 1/3 lb.	1075	110	____to____
Potatoes (dehydrated), 1/3 lb.	2225	550	____to____
Lettuce, 2 leaves	144	7	____to____
Apples (fresh), 6 oz.	499	88	____to____
Apple juice (canned), 3 oz.	295	45	____to____
Oranges (fresh), 3 oz.	351	46	____to____
Orange juice (frozen), 3 oz.	1172	46	____to____
Orange juice (canned), 3 oz.	394	45	____to____
Shelled pecans, 2 oz.	2426	405	____to____
Shelled almonds, 2 oz.	1947	363	____to____
Shelled walnuts, 2 oz.	2612	395	____to____

Procedure:

1. Calculate the energy ratio of the foods listed. Divide the "Energy to Produce" by the "Energy in Food." Round your answer to the nearest whole number. Example:

$$\text{Wheat bread: } \frac{\text{Energy to Produce}}{\text{Energy in Food}} = \frac{115}{61} = \frac{1.9}{1} = \frac{2}{1} \text{ or 2 to 1}$$

(It takes two times the food energy value of wheat bread to produce it.)

2. Record your answers in the space provided in Table 1.

Conclusion:

What factors determine the energy costs for food production and distribution?

Review for you:

Q1. Which five foods on the list would be considered the most energy-intensive? (Which foods have the highest ratio?)

Q2. Why are these foods so energy-intensive?

Q3. List the potato products in order of their energy ratios. Explain the differences.

Q4. These "Energy to Produce" values are averages. What factors are considered in calculating them?

Q5. Which would use less energy to produce, food grown in your own garden or food from the grocery store? Which of these usually costs less?

Q6. Packaging materials use energy, too. Here are some materials and the kilocalories per ounce used to produce them: paper, 321; glass, 120; steel, 233; aluminum, 1552; and plastic, 292. Consider the weight of 3 one-gallon milk jugs. Which jug would be the least energy intensive, glass, paper or plastic? What would be some other advantages and disadvantages of each kind of jug?

Think about this:

Q7. Why do fresh foods cost more when they are not in season? ("In season" means that it is the time of year that the food grows locally. Florida's "in season" is different from the "in season" of northern states.)

Q8. How did people preserve food 2000 years ago? They didn't have freezers or cans.

Q9. Plan a one-day menu for yourself. Select a balanced diet. Choose foods that are the least energy-intensive. Consider the packaging of foods purchased. If you want to choose foods from a garden at home, select only those foods that are ready for harvest now.

6 Now You're Cooking - With The Sun

Did you ever hear the expression "It's hot enough to fry an egg on the sidewalk"? Sidewalks don't really get quite hot enough to cook on. But you can build a "hot box" or solar oven that can collect the sun's heat energy and cook many different kinds of food. To work properly, a solar oven must hold this heat energy long enough for the food to absorb the heat and cook.

Collecting the energy is easy. Most solar ovens have a glass or plexiglass cover. Also, the designs usually include some kind of reflectors which increase the amount of energy the oven receives by reflecting light into the oven.

Holding the heat energy in the oven is the hard part. Ovens must be carefully insulated and tightly sealed so the captured heat cannot escape. Moist foods, such as stews, must be sealed so escaping water does not condense on the glass cover.

Foods that are easy to cook must be kept at 175°F or greater for two hours. These foods include white rice, rolled oats, pearl barley, squash and Indian pudding (cornmeal and milk).

Foods that are more difficult to cook must be kept at 175°F or greater for about three hours. They include lentils, blackeyed peas, black beans and potatoes.

Foods that are most difficult to cook must be kept at 195°F or greater for three hours, and they should be presoaked. These foods include pinto beans, garbanzo beans, small navy beans, kidney beans, red beans and split green peas.

Recipe

Sunshine cookies:

Mix 1 cup flour, 1 teaspoon baking powder, 1 teaspoon baking soda. Blend 1/4 cup margarine, 1/2 cup brown sugar, and 1 teaspoon vanilla extract. Add dry ingredients. Add 3/4 cup rolled oats. Mix well. Drop by spoonfuls onto cookie sheet. Cover with a loose tent of blackened foil. Bake in solar box cooker for about one hour.

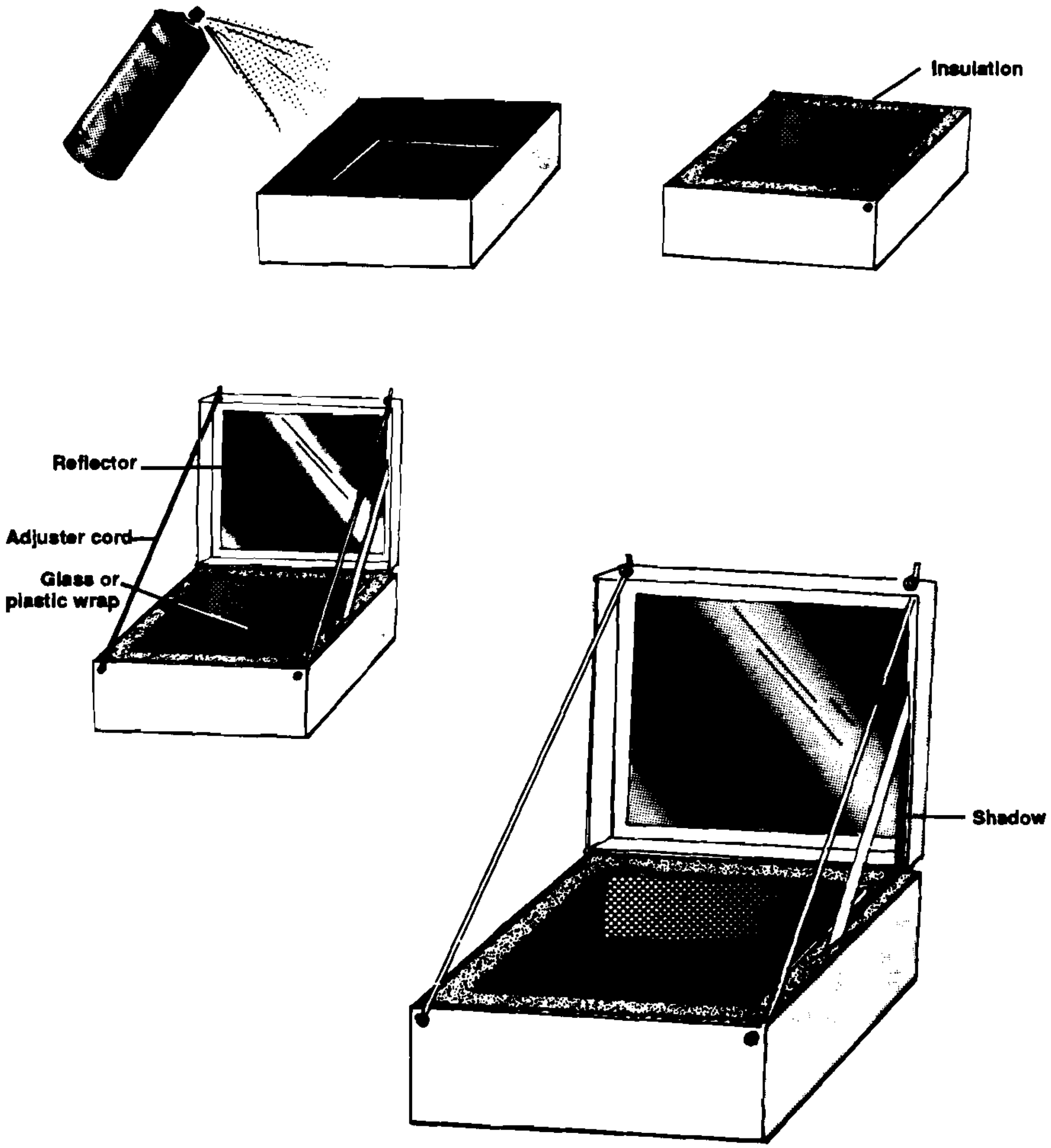
Name ______________________________ **Class** ____________________ **Date** ____________

Objective:
To build and use a solar box cooker

Materials:
Corrugated cardboard box, about 11 in. x 18 in. x 8 in.
Corrugated cardboard box, about 15 in. x 22 in. x 10 in.
Insulation to fit between the nested boxes (Wadded fiberglass works well.)
Newspaper or styrofoam "peanuts"
Sheet of plain glass or plexiglass about 12 in. x 19 in. (Plastic wrap can substitute.)
Mirror, about 12 in. x 19 in. (Mylar film [good] or aluminum foil [not as good] can substitute if you also have a stiff backing to glue it on.)
Cord or heavy string, 6 ft.
Scissors
2 sticks for props, each about 26 in.
Spray paint, dull black
Duct tape
Thermometer, Celsius or Fahrenheit
Dark cookware with dark lids (Use dark enamel, amber glassware, or cast iron; the lid can be blackened foil.) Hint - Make sure the pot will fit in the oven!
Cake rack to raise cookware
Food

Procedure:
Build the Solar Box Cooker
1. Cut the boxes so that the smaller one is about eight inches high and the larger one is about ten inches high.
2. Remove the top and spray paint the inside of the small box with dull black paint. (Hint - If you are going to paint the outside of your cooking pot and lid, do it now.)
3. The large box needs its top hinged along the 22-inch length. If it has been cut this way, fine. If not, cut the top off and make a hinge with duct tape.
4. With scissors or a compass point, CAREFULLY punch holes for the cord adjuster. Punch two holes near each outside corner in the top of the large box. (See illustration.) Punch two holes near each front corner in the base of the box.
5. Cut two adjuster plates from scrap cardboard. Each should be one inch wide and three inches long. (See illustration.)
6. Cut the cord into two 3-foot lengths. Knot one end of a cord, and thread the free end through the punched holes and the adjuster plate. Do the same on the other side. (See illustration.)
7. Use duct tape to fasten the mirror on the inside of the large box's top. The mirror is the reflector.

8. Put two inches of insulation in the bottom of the large box.
9. Set the small box in the large box, an equal distance from the sides. Put insulation between the two boxes.
10. Loosen the insulation enough to insert the prop sticks between the boxes. (See illustration.)
11. Cover the top opening with glass or plexiglass. Your solar box cooker is now complete.



Solar Cooker

Position the Solar Box Cooker

1. Place the cooker in full sunlight, on a dry surface. Prop the reflector open in any position temporarily.
2. Move the box east or west until the shadow of the prop falls directly behind the stick, parallel to the edge of the box.
3. Move the reflector until reflected sun lights up the inside bottom and front of the oven. Move the props until they hold the reflector in this position. Tighten the cord adjuster firmly.
4. If it is windy, put rocks or some kind of weights around the cooker to keep it in focus.

Use the Solar Box Cooker

On a clear and sunny day, the cooker will reach 280°F. This is hot enough to cook or bake almost anything, if you are patient. On a hazy or partly cloudy day, the cooker will reach about 225°F. You can cook meats, rice, potatoes or frozen vegetables, but don't try to bake bread or cakes. On completely cloudy days, the cooker won't work!

Be certain that all your cookware is tightly covered. If moisture escapes, it will condense on the lid and block the incoming energy.

Any conventional recipe suitable for an oven will work in a solar oven, but you will have to adjust the time to account for the lower temperature. A good rule is to double the regular cooking time. Crock pot recipes are great but since the solar cooker will get as much as 100°F hotter than a crock pot, cooking times may be shorter.

BE CAREFUL when you open the cooker. IT'S HOT INSIDE. Use potholders to handle the hot cookware.

1. Lift the glass or plexiglass lid from the top. Put the cake rack inside the solar cooker. Put in a thermometer so that you can read it when the lid is closed. Record the temperature. Close the lid and focus the cooker. Preheat for 30 minutes.
2. Record the temperature. Open the lid. Put covered dark cookware containing your food on the cake rack. Close the lid.
3. Record the temperature inside the cooker every 15 minutes.
4. Measure your cooking time. When the estimated cooking time is up, record the temperature, carefully open the lid, remove the hot cookware, and sample the food. If the food is not yet done, cook it a bit longer. Be patient!

Conclusion:

Describe the temperature changes and the foods you cooked. Include a labeled drawing of the solar box cooker. How could you improve the design of your cooker?

Think about this:

Q1. What are some other ways you can use the heat energy from the sun?

Q2. What are some advantages and disadvantages of using the sun's energy for cooking?

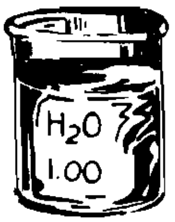
Q3. Identify some cultural problems that might prevent the widespread use of solar cookers.

Q4. Conduct some library research on the history of solar cookers. Look for information about how they are being used in Third World countries that are running out of fire wood.

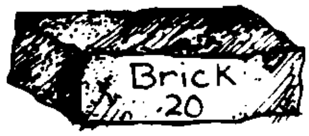
6 Storing Solar Energy

Scientists and engineers are developing ways to store the radiant energy from the sun as heat energy. This heat energy could be used at times when direct solar energy is not available. Materials differ in their ability to absorb heat. The ***specific heat capacity*** (s.h. or sometimes Cp) of a material is a measure of its ability to absorb heat. Materials with high specific heat values absorb and release more heat energy than materials with lower specific heat values.

The specific heat capacity of materials are measured in laboratories under controlled conditions. Some specific heat values are:



Material	**Specific Heat (cal/g per °C)**
Concrete	.16
Cinder block	.18
Brick	.20
Limestone	.22
Wood	.42
Water	1.00

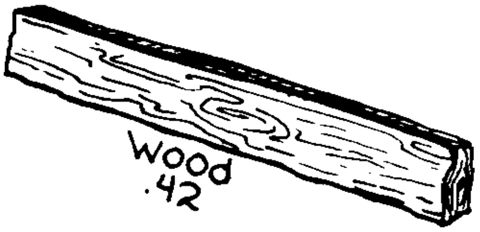


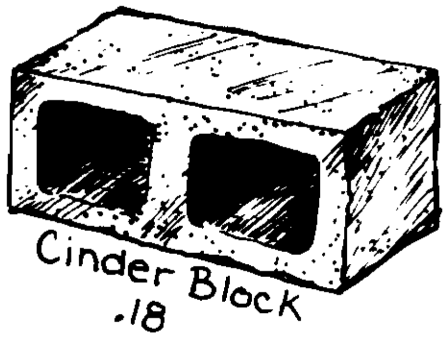
The table shows that water absorbs heat slower than bricks or concrete. Water also retains heat longer; it does not lose heat as fast. Of course the mass or weight of the material is also important. From the chart you can see that five kilograms of bricks will be needed to hold as much heat as one kilogram of water.

Specific heat capacity can be used to calculate the amount of heat energy absorbed or lost by a substance. The heat absorbed or lost is equal to the product of the mass (M) times its change in temperature (ΔT) times its specific heat (s.h.) or:

$$\text{Heat gained or lost} = M \times \Delta T \times \text{s.h.}$$

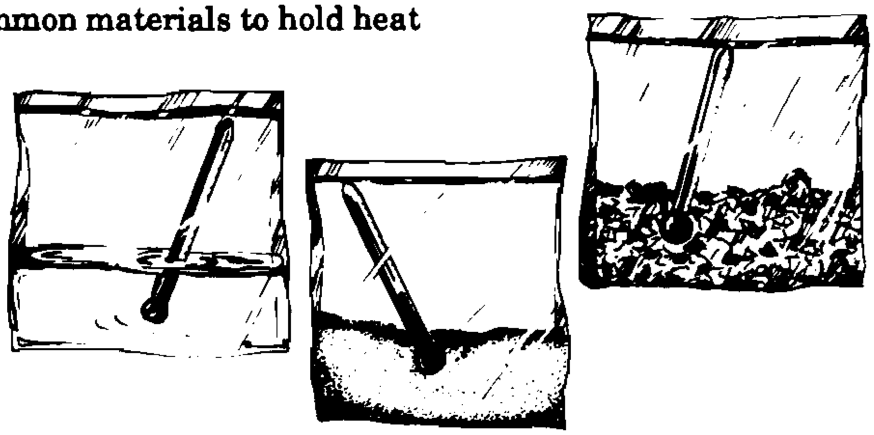
Homes designed to capture, store and distribute heat energy are not new. Both ancient Greeks and Romans designed systems to store solar energy in the form of heat. In fact some very interesting "solar homes" were built by the Pueblo Indians in America's Southwest. In this activity you will measure the ability of different materials to hold heat energy.





Name ______________________ Class __________________ Date ___________

Objective:
To measure the ability of some common materials to hold heat



Materials:
Water
Sand
Cement or pieces of concrete block
Limestone or crushed seashells
Scale to weigh materials
Thermometers
Clear sealable plastic bags

Procedure:
1. Carefully weigh 250 grams each of water, sand, concrete block, and limestone or crushed seashells.

2. Place each substance and a thermometer in its own sealable plastic bag and record the starting temperature (Ts). Position the thermometer so you can read it without removing it.

3. Put the bags in a place where they will get full sun but will be protected from any wind.

4. Record the temperature in each bag every five minutes for at least 20 minutes.

5. Bring your experiment inside or put it in the shade. Open the plastic bag and record the temperature drop of the materials every five minutes for 15 minutes.

Measuring Heat Storage of Materials

Time	Water Temp.	Sand Temp.	Concrete Block Temp.	Shells Temp.
Start				
5				
10				
15				
20				
25				
30				
35				

6. Use this formula to calculate the amount of heat the materials absorbed before they were taken out of the sun. Heat gained or lost = M x ΔT x s.h.
7. Use the formula to calculate the amount of heat the materials lost after they were removed from the sun.

Conclusions:
Write a paragraph about your experiment. Include a list showing which materials gained the most heat and which ones stored heat the longest.

Which materials retained or stored the most heat?

More:
Repeat this experiment using other materials. Are metals good materials for storing heat?

Review for you:
Q1. What is specific heat capacity? ____

____

Q2. Why is the specific heat capacity important in solar heating systems?

____

____

Q3. Why is it important to keep the mass of the materials nearly the same when measuring their ability to store heat?

____

____

Think about this:
Q4. Visit the library and investigate the use of ***Glauber's salts*** to store solar heat.

Q5. Space heating is not a very important energy use in most Florida homes. How can the specific heat capacity of materials be used to keep homes cool? Remember there is no such thing as cold, just a lack of heat.

Q6. Visit the library and investigate the use of ***heat pipes*** to moderate temperatures. Prepare a report for the class.

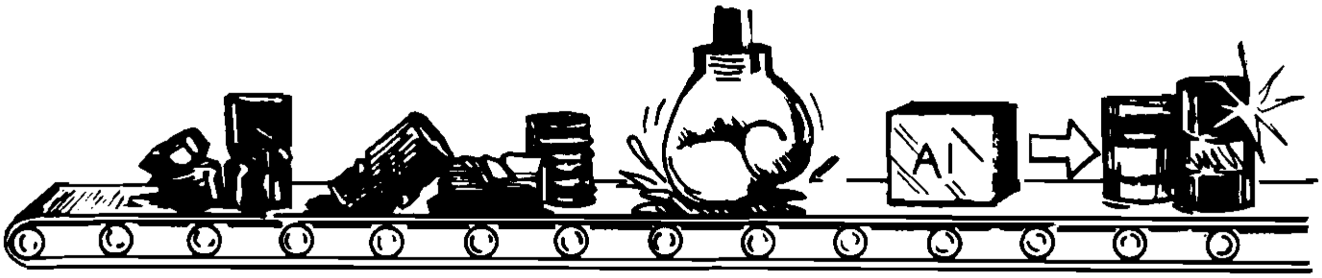
Q7. Investigate the buildings constructed by the Anasazi Indians at Meas Verde, Pueblo Bonito and Acoma. What can we learn from them about how to design buildings?

7 Recycling and Your Environment

Recycling is one way of reusing discarded materials. It is a sensible way to reduce the amount of waste we produce. For many materials, there are environmental benefits from recycling. Table 1 shows some of these benefits. For example, it takes 95% less energy to make aluminum cans from recycled aluminum than it does to make them from bauxite (the principal ore from which we extract aluminum).

Table 1. Environmental Benefits from Recycling

		Recycled Material			
		Aluminum	Steel	Paper	Glass
You reduce:	Energy Use by	95%	60%	33%	20%
	Air Pollution by	95%	85%	74%	20%
	Water Pollution by	97%	76%	35%	-
	Mining Wastes by	-	97%	-	80%
	Water Use by	-	40%	58%	50%

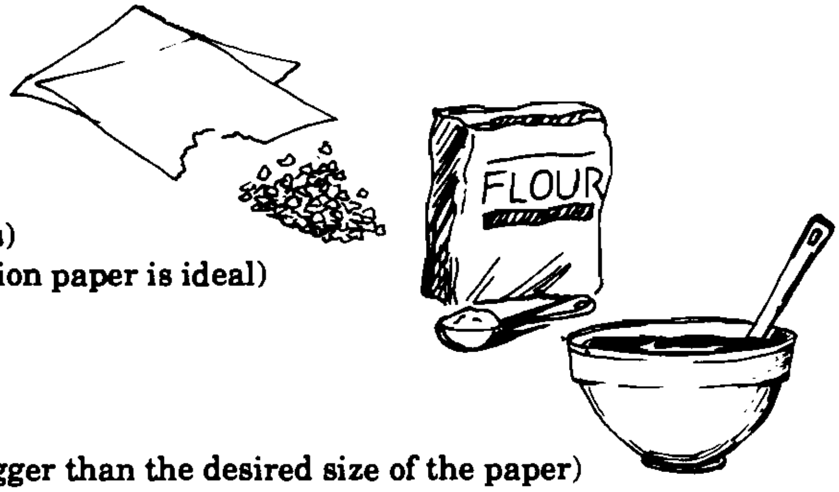


Glass can be recycled into new glass for bottles and many other products. Plastic bottles can be recycled into fiberfill for pillows and jackets. Wastes from farming can be converted to alcohol fuels and methane. The remaining materials can be used as animal feed or as soil enrichers. Paper products make up the bulk of our waste stream.

About 30% of the paper is clean enough to recycle. It is easy to sort out and there are good reasons to do so. Paper, particularly newsprint, is in short supply. Much of our newsprint is imported from Canada and other countries. One scientist has estimated that recycling one ton of paper saves 17 trees! If two-thirds of the trash paper could be separated out and recycled, 450 million trees could be saved each year. The cost of collecting, transporting, separating and reprocessing makes some materials very expensive to recycle. Fortunately, making recycled paper requires less than one third of the energy needed to make it from primary sources.

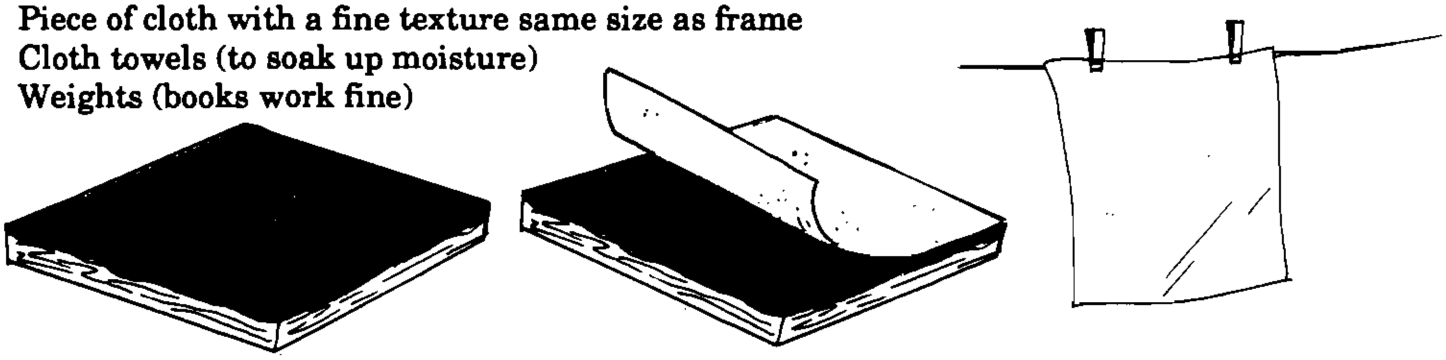
Paper can be used to make more paper, insulation, and building materials. In this activity you will use paper to make your own recycled paper.

Name ______________________ **Class** ________________ **Date** ________



Objective:
To make recycled paper from paper

Materials:
Scrap notebook paper (at least 4 sheets)
Small piece of colored paper (construction paper is ideal)
2 teaspoons flour or cornstarch
Bowl (1 to 2 quart size)
Blender or rotary egg beater
Water
Piece of screening or fine nylon net (bigger than the desired size of the paper)
Frame or embroidery hoop to hold the piece of screening (can be made from a picture frame with clothes pins or staples to hold the screening)
Aluminum foil or plastic wrap
Piece of cloth with a fine texture same size as frame
Cloth towels (to soak up moisture)
Weights (books work fine)



Procedure:
1. Tear the paper into 5 mm pieces (size of half your little fingernail). Don't cut the paper. You need the rough edges to soak up the water. Put the pieces in the bowl.
2. Add the flour. Add enough water to just wet the paper. Knead the paper pieces until they break apart and form a pulp. If you have one, use a blender or rotary beater to speed this step. Add a little more water if necessary. The pulp should be as thick as split pea soup.
3. Put the framed screen over a sink.
4. Spread the pulp evenly over the screen.
5. Let the water drain from the pulp until it stops dripping.
6. Put a piece of aluminum foil on top of the pulp.
7. On a flat surface, stack a towel, the screen/pulp/foil "sandwich," and weights. Instead of weights, you can use a water-filled jar as a rolling pin to squeeze out the water, or you can sit on the "sandwich."
8. Replace the towel under the "sandwich" with a dry towel as often as needed to soak up the water. Do this for at least 15 minutes.

9. Separate the stack. Invert the "sandwich" and carefully remove the screen. Let the paper dry completely (about two days).
10. Peel off the aluminum backing and trim the paper to the desired size.

Conclusions:
Describe your recycled paper. Can you write on it? Does it tear easily? What are some of the "costs" of recycling? Write a paragraph describing your recycling efforts. Be sure to include an estimate of how much energy you used during this activity!

More:
- Repeat this activity with other kinds of paper -- paper towels, toilet paper, newspaper, brown paper bags, etc. Compare the product with the paper made from notebook paper.

Review for you:
Q1. What does the term "recycling" mean? ______________________________

____

Q2. What are some environmental benefits from recycling? __________________

____

Q3. What are some by-products of wastes from farms? ______________________

____

Q4. What are some reasons to recycle paper? ___________________________

____

Q5. Why is recycling paper a better choice than burning it? ________________

____

Think about this:
Q6. How is "new" paper made? Visit your library and prepare a short report to give to the class.

Q7. Look up recycling (or scrap) dealers in the phone book. Call on dealers and get a price list for the materials they recycle. Prepare a report on the dollar value of recycled materials.

Q8. Explain how recycling can reduce energy use, air and water pollution, and water use.

Q9. Most people believe that recycling is "good," yet few people bother to recycle even modest amounts. What kinds of rewards would make people recycle more materials?

8 It's Getting Crowded

Florida's population is expected to be at least 15 million by the year 2000. It is hard to believe that just 60 years ago there were only a million people here! More people means more air pollution from car emissions and industrial pollutants. It means more water pollution from sewage and industries and from chemicals in the runoff from farms, cities and suburbs. It means more land is being used for roads, homes, and industries. More people means fewer areas for wildlife and natural beauty. More people means a greater demand for all Florida's natural resources, especially energy and water. More people may mean that you can't live the life-style you expect. Table 1 shows how Florida's population is growing and is expected to grow by the year 2000.

Table 1. Population of Florida (in Millions)

Year	Population
1920	1.0
1930	1.5
1940	1.9
1950	2.9
1960	4.9
1970	6.8
1980	9.7
1981	10.2
1982	10.4
1983	10.7
1984	11.0
1985	11.4
1986	11.7
1990	12.3
2000	15.0 or more

Florida's population has about doubled every 20 years. Compare 1920, 1940, 1960, and 1980. If that rate continues, soon after 2040 Florida will have ten times its 1980 population. If Florida has only the same natural resources, can you and your family live on just 10% of the food, water, and energy that you use today? You would have to make great changes in how you use all resources and find substitutes for resources that are in short supply.

Natural resource consumption and population growth are closely linked. In this activity, you will measure how increases in a yeast population affect the rate of resource use. The resource is oxygen.

Name ______________________ **Class** ________________ **Date** ________

Objective:
To measure how population growth increases the rate at which resources are used

Materials:
2 baby food jars
1 level teaspoon of powdered milk
1 level teaspoon of dry yeast
1 dropper bottle of methylene blue solution (available at tropical fish stores)
2 five-ml air pistons or hypodermic syringes
Dropper
2 teaspoons
4 test tubes (all the same size with a capacity of at least 10 ml)
1 test tube rack
Glass marking pencil
Watch or clock

Procedure:
1. Stir one level teaspoon of powdered milk into 20 ml of tap water in a baby food jar.
2. Stir one level teaspoon of dry yeast into 20 ml of tap water in another baby food jar. Stir again just before using.
3. Label the tubes #1, #2, #3, and #4.
4. Using an air piston, add four ml of the milk solution to each test tube.
5. Add 15 drops of methylene blue solution to each tube. Mix thoroughly. Methylene blue is an indicator. The blue color shows the presence of dissolved oxygen. As the oxygen is used, the blue indicator becomes colorless.
6. Mix tube #1 thoroughly but quickly. Record the exact time the mixing ends. Once the timing has begun, don't disturb the tube. Bumping it will introduce air into the liquid.
7. Add two drops of the yeast solution to test tube #2. Quickly mix and record the time.
8. Add one ml of the yeast solution to test tube #3. Quickly mix and record the time.
9. Add five ml of the yeast solution to test tube #4. Quickly mix and record the time.
10. Observe the changes carefully. For each tube, record the time when you see that the blue color has disappeared from all but the surface area (oxygen in the air).
11. Put your data in a chart like this:

Rate of O_2 Consumption

Test Tube	Time of Mixing	Time Change Observed	Elapsed Time
#1			
#2			
#3			
#4			