Energy-Efficient Homes

Objectives

The students will do the following:
1. Use models to learn how to maximize the comfort-conditioning of a home.
2. Observe, gather, and analyze data from the model simulations.
3 Draw conclusions from the data

Subjects:
General Science, Physical Science

Time:
4 class periods (Activities 3 and 4 can be activities for the whole class, and each requires one class period)

Materials:
large newsprint pad, drawing paper, several colored pens, rulers, protractor, student sheets (included)
Activity 3 - cardboard box, piece of white posterboard, compass, clear plastic wrap, flat black paint or black construction paper, thermometer, masking tape
Activity 4 - hot plate, watch, metal stem thermometer (0-100^{o} C), large beaker, ¼" thick plywood, ½" thick fiberglass, ceramic tile, 2 plastic straws of different diameter, tape

Background Information

Among the factors influencing the energy efficiency of home design are site analysis, home orientation, configuration, envelope, space planning, ventilation, heating, cooling, lighting and appliances, water heating, and waste management A brief explanation of each of these factors follows.

Site analysis is the recognition and use of natural elements of a home's setting for its energy efficiency. An example might be siting a home to take advantage of wind breaks to the north.

Home orientation includes facing a house and planning its windows to maximize solar heat gain in winter and minimize it in summer.

The home design's **configuration** should balance the benefits of using natural lighting and minimizing perimeter wall areas. To increase southern exposures (i.e, solar access), the optimal configuration is generally a form elongated in the east-west direction.

Envelope considerations include the glass and exterior wall materials selected, as well as structural design

Good **space planning** arranges various home activity areas appropriately. For example, the kitchen/dayrooms might share the east/south sides of the home.

Ventilation includes the controlled intake of fresh air, its circulation, and its exhaust

Heating needs in Tennessee Valley homes are usually greater than cooling needs. Home heating generally consumes more energy than any other home energy use (approximately 40 percent). Heating systems include electric resistance heating (e g, electric wall heaters), gas furnaces, wood heaters, and electric heat pumps. Central heating systems deliver heated air or water to all parts of the home. Heating (and cooling) systems are usually controlled by a thermostat.

Cooling systems in Tennessee Valley homes are almost always window or central air-conditioners that use a compressor and refrigerant to cool and dehumidify the air in side the home.

Lights and appliances are usually powered by electricity. An exception would be gas stoves. Well-designed windows or skylights can be used to provide "daylighting." One factor to consider when purchasing appliances is their energy efficiency rating. The location of appliances within the living space and the ways in which they are used and maintained must also be considered.

Domestic **hot water** is the term for heated water used for washing and bathing. As much as 25 percent of an all-electric home's electricity bill comes from heating water.

Energy waste management should always be considered in the design of large buildings. Waste management systems for homes are generally rudimentary. An insulation blanket for a water heater is a simple form of waste management. Another is the fresh air intake control device on heating/air conditioning systems. We will begin to see more frequent use of air-to-air heat exchangers to preheat incoming fresh air as a waste management feature in new systems.

Procedure

I. Give each student a copy of the student sheet "ENERGY-EFFICIENT STRUCTURES-Introduction" included. Using the background information, introduce the eleven factors given for energy-efficient homes to the students.

II. Divide the class into nine to eleven groups. Assign each group one of the student activities and give the members of the groups the student sheets for their activities. They are to complete the activities and then develop a presentation for the class based on their findings. Encourage them to do further research and to make visual aids. Tell them that their job is to convince their classmates to conserve energy.

III. Allow at least four class periods to complete this activity.

A Allow one period for students to learn about the eleven factors for energy efficient homes

B. Allow one period for students to complete their group assignments and plan their class presentations.

C. Two periods, after the groups have had a chance to do research or make visual aids, will be needed for presentations. Be sure to tell the groups how much time they have for their presentations (e g five minutes per group).

IV. You may wish to reserve the “CONFIGURATION” and “ENVELOPE” activities for whole-class participation. In this case, there would only be nine activity groups. Allow one class period for each of these two activities.

V. Continue with the follow-up below.

Follow-Up

I. After the class presentations, some effort should be made to compare design features recommended by individual groups for the same design element. For example, compare the south-facing window placement and areas specified by the space planning, ventilation, and configuration groups.

II. You may wish to have a representative from your local utility company, a solar energy advocacy group, or a building or architectural firm visit your class.

Resources

American Institute of Architects *Energy Conservation in Building Design*. N p . Author, 1974.

Edison Electric Institute. “Energy Management in the Home.” N.p.: Author, [1987].

Mazria, E. *The Passive Solar Energy Book* Emmaus, PA Rodale, 1979

Tennessee Valley Authority. *Energy Saver Home Standards*. N.p: Author, [1981].

ENERGY-EFFICIENT STRUCTURES

Introduction

Energy-efficient structures result from careful consideration of the following design factors

1. Site Analysis
2. Home Orientation
3. Configuration
4. Envelope
5. Space Planning
6. Ventilation
7. Heating
8. Cooling
9. Lighting and Appliances
10. Domestic Hot Water
11. Energy Waste Management

All-electric homes in the Tennessee Valley tend to consume the following relative amounts of electricity for the consumption categories listed:

Heating	44%
Domestic hot water	22%
Cooling	12%
Lighting	10%
Refrigeration	5%
Cooking	4%
Clothes drying	3%

Of course these percentages will vary as locations, homes, heating/cooling systems, appliances, and even the residents' habits vary.

Assignment

Each group is to complete the student activity sheet assigned to it and then develop a presentation to be given to the class. First you will meet as a group to discuss how your assignment is to be completed. Then plan your group presentation. Try to be innovative in the ways you present your findings. Use examples from your own homes and school buildings.

ENERGY-EFFICIENT STRUCTURES

Activity 1: Site Analysis

Homes should be sited to take advantage of natural features of the terrain, which offer energy conservation help. For example, a home site may offer windbreaks or summer shade. You have probably heard how one can use the sun's energy to heat a home. To benefit from the winter sun's heat, trees near the south wall of your home should be deciduous. Using your personal knowledge, perform the following procedure. Afterwards, at home or in the library, you may gather additional information to substantiate your conclusions.

1. List terrain features that can help to make a home more energy efficient.

2. Explain how each feature can contribute to energy efficiency.

3. Visit the site of a new house or housing development. Examine the siting of the home(s). Draw a map showing compass directions, a new home, and natural features that make the new home more energy efficient. The map need not be elaborate. Here's an example:

NEED TO SCAN IN ART

4. Describe the new home

5. Using a different color pen, add to your map the landscaping changes you would make to improve the home's energy efficiency

ENERGY-EFFICIENT STRUCTURES

Activity 2: Home Orientation

The sun can help heat our homes in winter. If we use air-conditioning in summer, the sun can increase our energy use and bills unless we provide sun controls. Sun controls that might be used include (deciduous) shade trees, roof overhangs, windows blinds and drapes, and thermal insulation. If the south-facing glass area is limited to approximately 10 percent of the comfort-conditioned living space area in a house in the Tennessee Valley, there should be more winter energy savings than summer losses (i.e. a net decrease in annual energy used for heating and cooling). Using your personal knowledge, perform the following procedure. Afterwards, at home or in the library, you may get additional information to substantiate your conclusions.

1. List the uses of windows.
2. Think about the position of the sun relative to your location. Describe summer sun positions at daybreak, noon, and sunset. Describe winter sun positions at these same times.
3. If you were a real estate developer and you wished to develop a subdivision in which the homes are designed to maximize energy conservation, you would have to orient the houses properly. Draw a simple aerial map showing the compass directions and the meadows and hills where you will construct the "Sunny Acres" Subdivision. Draw the nearest road that leads into town
4. Now, plan the access streets that will lead to the main road and select the lot on which you will build your own new home.
5. Draw your new home on the map. Your map may look something like this one.
6. Mindful of your household activities and your intention to use heat from the sun, sketch a simple floor plan showing the walls, doors, and windows of your new home.
7. How will you prevent unwanted summer sun from entering the windows? How will you prevent heat loss through the windows during winter? Identify special features you wish to include.

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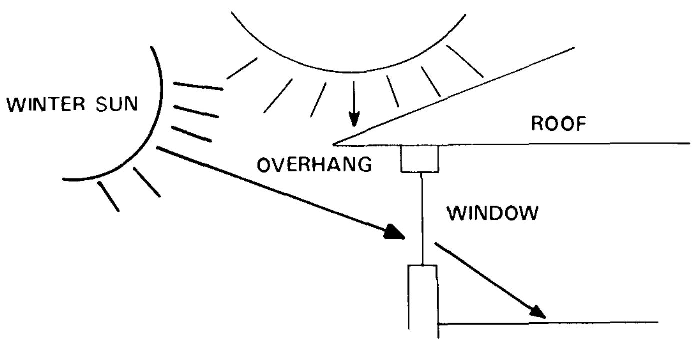
ENERGY-EFFICIENT STRUCTURES

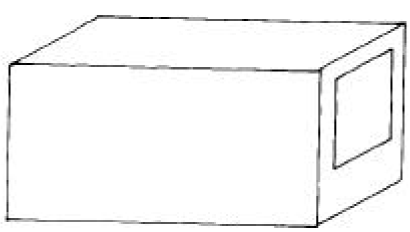
Activity 3: Configuration

This activity may be used with the whole class



People have long been aware of the heating effects of the sun. Utilizing the sun's heat in the winter and avoiding it in the summer helps to cut down on heating and cooling costs. Structures can be designed to conserve energy in both winter and summer. This investigation considers the manipulation of a "roof overhang" to illustrate using a shading device to promote the natural cooling of a house.

Perform the following procedure and log your data on the data sheet. Refer to the provided drawings for guidance. Be prepared to demonstrate this experimental procedure during the class presentation.



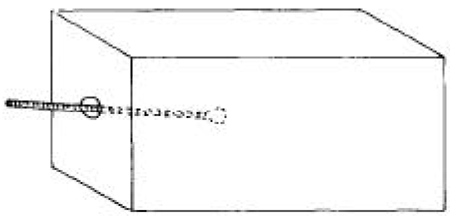
1. Cut a hole in one side of a cardboard box. This will be a window. Make sure the window is placed closer to the top of the box than **it** is to the bottom.

2. Paint all the inside surfaces of the box flat black (or cover them with black construction paper).

3. Cut a piece of white posterboard for the roof long enough to make sure the roof covers the entire box and extends over the edge to completely shade the window.

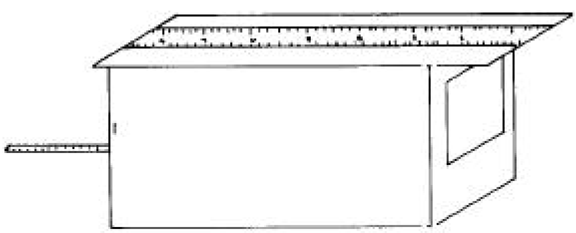
4. Use plastic wrap to cover and seal the hole in the side of the box. Tape the plastic around the edges.

5. Make a small hole toward the back of the box. The hole should be large enough to insert the thermometer. Make sure the bulb of the thermometer is measuring the air temperature in the box. It should not be in direct sunlight.



6. Tape a ruler to the "roof" piece. This will allow you to easily measure the amount of roof overhang.

7. Set this model "house" up outside in direct sunlight around midday. The window should be facing south.



8. Place the roof so that the window is completely shaded. Wait about 5 minutes (until the temperature has stabilized) and record the temperature in the box. Also record the air temperature outside the box.

9. Move the roof a few centimeters at a time, so that the window is shaded to the different degrees given in the data table. Each time record the temperature after it stabilizes. Do this until you have measured the temperature of the box when its window is in full sun. Be sure to measure and record the outside air temperature, too.

DATA TABLE

Amount of roof overhang (cm) when shading:		Temp Inside (^oC)	Temp Outside (^oC)
all of the window	______ cm	__________	__________

3/4 of the window	______ cm	__________	__________
1/2 of the window	______ cm	__________	__________
l/4 of the window	______ cm	__________	__________
none of the window	______ cm	__________	__________

10. Estimate the width of roof overhang needed in the Tennessee Valley by sketching to scale the south wall (assume **it** is all window) and determining the roof overhang needed when the noon sun is 75 degrees above the horizon. For this exercise, assume the roof is a flat one as in the model.

Discussion Questions

1. Is roof overhang important for north-facing windows? Would your answer be different if you were living in Australia?

2. From the estimate you made of roof overhang needed in this region, what can you deduce about the placement of deciduous shade trees to the south?

3. Think about the way the sun seems to move from east to west during a day. What can you say about shade tree placement to diminish afternoon ~

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Activity 4: Envelope*

It is important to "weatherproof" a home, that is, to insulate, to caulk, and to weatherstrip doors and windows. Insulation is any material that slows the movement of heat from one place to another. It slows the flow of heat entering the house during the summer; it slows the flow of heat leaving the house in the winter. The effectiveness of insulation in slowing the flow of heat is measured in resistance or "R-value." The higher the R-value, the better the insulating potential. Both thickness and composition are important factors in insulating effectiveness. For example, fluffy fibrous insulations should not be compressed before or during installation. In this experiment you will compare the effects of both thickness and composition on insulating capability.

CAUTION: This experiment should be done under your teacher's supervision.

1. Turn on the hot plate. If it has a warm setting, use it. Measure the stabilized hot plate temperature with a metal stem thermometer (0-100 ^{o}C) and record it in the data table.
2. Measure and record the thickness of the ceramic tile. Lay it on the hot plate.
3. Measure and record the tiles top surface temperature each minute for 5 minutes. Now take readings every 2 minutes for 10 minutes. Take a final reading 5 minutes later. Record all the temperatures in the data table. Remove the tile from the hot plate using heat-protective gloves.
4. Measure and record the thickness of a piece of plywood. Lay it on the hot plate. Record the temperatures as you did for the tile.
5. Measure and record the thickness of a piece of fibrous insulation bat. (If you are using

fiberglass, wear gloves when handling it.) Heat the insulation, measuring and recording the insulation’s top surface temperature after 3, 6, 9, 12, and 15 minutes.

6. As a home assignment, plot the surface temperatures of the tile, plywood, and insulation as a function of time. Which surface’s temperature rises faster?
7. Place a beaker of water on the hot plate and heat it until the temperature of the water stabilizes. While the water is heating, make an insulating sheath by inserting a smaller diameter straw inside another one, folding the straws at their midpoint and wrapping tape around them to hold the ends together.
8. Insert the thermometer into one of the open ends of the straw sheath, and place the apparatus in the beaker of water. Use a watch to time how long it takes the temperature measured by the thermometer to equal the water’s temperature.
9. Turn off the hot plate.
10. Explain why the insulating sheath you made of straws worked.

*This activity may be used with the whole class.

DATA TABLES

Stabilized Hot Plate Temperature ___

Ceramic tile

Thickness: ___________ cm	
Elapsed Time (minutes)	Temperature (00)
1	
2	
3	
4	
5	
7	
9	
11	
13	
15	
20	

Plywood

Thickness: ___________ cm	
Elapsed Time (minutes)	Temperature (00)
1	
2	
3	
4	
5	
7	
9	
11	
13	
15	

20

Insulation

Thickness: ___________ cm	
Elapsed Time (minutes)	Temperature (00)
3	
6	
9	
12	
15	

Water

Water Temperature: _____________ ^{o}C Time required to reach water temperature (above) when insulating sheath is used: ______minutes

DISCUSSION QUESTIONS

How well does the tile conduct the heat of the hot plate? Would tile be useful as insulation? Why or why not? What about the plywood?

2. How do you think the thickness of the insulation bat affects its insulating ability?

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Activity 5: Space Planning

The sun's warmth and light can make a good house even better. Think about your own family's activities and then design the interior room arrangement of an energy-efficient, passive solar home, performing the following procedure. Afterwards, at home or in the library, gather additional information.

1. Where in the house are family members in the morning, at mid-day, in the evening, and at night? What kind of space and comfort-conditioning do they need at these times?

2. Draw a floor plan, showing compass directions, for a new home. Lay out the general arrangement, locate doors and windows, and then partition the space into rooms and storage spaces. Don’t forget the need for convenient emergency exits and good traffic flow patterns.

3. Suggest construction materials (e.g., wood paneling, brick, tile), wall colors (e.g., light, dark, warm, cool), and lighting types to maximize the convenience, comfort, and energy conservation of your floor plan.

ENERGY-EFFICIENT STRUCTURES

Activity 6: Ventilation

Home ventilation is the controlled intake of fresh air, its circulation, and its exhaust. Average home construction results in inside air being exchanged one time each hour. Tight construction can reduce this to perhaps one-half an air change per hour. Fresh air enters the house through windows, doors, intake louvers on comfort-conditioning equipment, and infiltration or leakage. Many new homes have kitchen and/or bathroom exhaust fans that tend to induce a flow of outside air by reducing inside pressure slightly. Outside air is sometimes supplied to the fireplace grate. Vents are always included in attic or crawl spaces to reduce humidity.

Using your personal knowledge, perform the following procedure. Afterwards, at home or in the library, gather additional information to substantiate your statements.

1. Draw the floor plan of a new house to approximate scale, noting on your drawing the compass directions and the length, width, and height of your home. (You need not show inside room partitioning unless the ceiling height in the house is not uniform). Calculate the amount of floorspace in the home and its total air volume. Relate the air volume to anticipated air changes.

2. Make a fairly complete list of the places where air leakage is likely. What are the remedies for each leak?

3. Discuss different types of windows and doors and rate them for their likelihood to cause air leakage.

4. Where could fixed glass windows (i.e., windows that don’t open) be used effectively? Look up in the dictionary the word “clerestory,” noting both its meaning and pronunciation. Clerestory windows are often used in conjunction with “cathedral” ceilings. They do one thing exceptionally well Can you think what that might be?

5. Describe what is meant by “cross-ventilation.”

ENERGY-EFFICIENT STRUCTURES

Activity 7: Heating

Heating is very important in Tennessee Valley homes because we have many cold days and nights. Using your personal knowledge, perform the following procedure. Afterwards, at home or in the library, find information to substantiate your choice. You may be able to get a fast overview of heating system types by talking to a heating contractor.

1. Using the following outline, briefly describe some of the heating systems used in the Tennessee Valley. Give both their advantages and disadvantages.

A. Room Heaters
   a. electric resistance
   b. wood
   c. gas
   d. oil
   e. coal solar

B. Central Heating Systems (circulating heated water or warm air)
   a. electric resistance
   b. heat pump
   c. gas
   d. oil
   e. coal
   f. wood

2. Discuss the relative costs of these systems, their efficiencies, and their maintenance requirements.

3. Discuss the likely availabilities and costs of the above fuels during the lifetimes of these systems.

4. Select a heating system for a new Tennessee Valley home. If you were building a home for yourself, what kind(s) of heating would you use? Why[7]

ENERGY-EFFICIENT STRUCTURES

Activity 8: Cooling

Homes in the Tennessee Valley often have window air-conditioners or central air-conditioning systems which use compressors and refrigerants to cool and dehumidify inside air. Using your personal knowledge, perform the following procedure. Afterwards, at home or in the library, gather additional information to substantiate your choice (You may want to talk with a cooling systems contractor for more information).

1. How would you describe the Tennessee Valley's summer climate? Does it vary widely

from east to west? If so, why? Does it vary widely from north to south?

2. Discuss what you know about relative humidity and compare the relative humidities of a steam bath or sauna, a summer baseball game, and a cave. What happens when warm, moist air is suddenly cooled? What happens when you go outside on a cool, breezy day with wet hair?

3. Air conditioners and heaters are usually controlled by thermostats. Do you know how your parents control their cooling system? Do family members agree on daily settings for the cooling system control? If no one will be home, is it economical to leave your air conditioner running?

4. What do you know about heat pumps? They can be thought of as reversible air conditioners, supplying cool air in summer and warm air in winter. Because they use refrigerants, heat pumps can absorb heat from cool air in winter effectively. (You won’t need to select a separate air conditioner if the “Heating” group selects a heat pump)

5. Compare the efficiency of different brands of air-conditioners. To do this, you will need to compare their Energy Efficiency Ratios (EER). The Energy Efficiency Ratio is defined as the rate at which the device removes heat from the surroundings. It is usually expressed in British thermal units (Btu) per hour divided by the rate of energy input (watts) required to operate the machine. Select a group member to call one or two appliance stores to find out what typical EERs are (note brand names also) and what the expected annual operating costs might be (they may not know this).

6. It is important not to have more air-conditioning capacity than is needed. It is better to have one that runs more and, in doing so, removes more humidity. Make sure the appliance dealers take the energy efficiency of your house into account when sizing a cooling system for it. Air conditioners are often rated in tons. A ton of air-conditioning is usually expressed as 12.000 Btu per hour. A window air conditioner may range in size from 3/4-ton to two tons. Find out what size was most often used in houses that are now 15 to 20 years old Find out what size is most often used in newly completed houses of about the same size.

7. Select a cooling system from among those you have researched.

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Activity 9: Lighting and Appliances

The category “Lighting and Appliances” usually accounts for just over 20 percent of the energy consumption in an average Tennessee Valley all-electric home. Typically the big three users are heating (44 percent), hot water (22 percent), and cooling (12 percent). Lighting consumes about 10 percent of the electricity used in a typical home. The lesser three are refrigeration (5 percent), cooking (4 percent), and clothes drying (3 percent). Your job is to select a new home lighting system, explore ways to select energy-efficient appliances, and make suggestions for managing home energy use wisely Perform the following procedure. Afterwards, at home or in the library, gather additional information to substantiate your conclusions.

1. Although sharp changes in light intensity should be avoided, adequate light should be directed to areas that especially need it, e.g. where people read, at a work bench, or on the kitchen counter Fluorescent lighting tends to be cooler than incandescent lighting and about twice as efficient. The term “cooler” means both cooler in terms of temperature and in having a cooler appearance to the eye. Mixing in some incandescent lighting produces a warmer, cheerier look. With these things in mind, and supplying personal knowledge and opinion, design a lighting system for a new home. Draw a sketch showing light fixture placement in the kitchen, the living room, and a bedroom. Try to decide what light-related qualities wall and floor coverings should have. Don’t forget to consider window placement and how it will affect lighting needs.

2. Here are some estimates of the annual energy consumption of various appliances. The numbers are kilowatt hours.

range with oven	1152	clothes dryer	1000
microwave oven	300	clothes washer	624
frying pan	190	dishwasher	1560
coffee maker	110	hand iron	150
toaster	40	color tv,	
clock	18	solid state	440
mixer	10	b&w tv.	
refrigerator/freezer,		solid state	120
17 cu ft, 2-dr,		radio/phonograph	110
auto defrost	1200	vacuum cleaner	50
attic fan	300	dehumidifier	400
ceiling fan	130	electric blanket	150

Select one appliance that uses a lot of energy and find out (1) if annual average energy use for different brands are available, (2) how three brands with the same features compare in energy consumption, and (3) if the number given in this table is reasonably accurate.

3. For the appliance selected, list some measures which, if followed, will reduce its energy consumption

ENERGY-EFFICIENT STRUCTURES

Activity 10: Domestic Hot Water

The average Tennessee Valley family uses approximately 5,400 kilowatthours of electricity in a year to heat water. Using your personal knowledge, perform the following procedure. Afterwards, at home or in the library, gather additional information to substantiate your conclusions.

1. Here are some ways to reduce the energy consumed by heating water:
   a. Fix leaking faucets
   b. Use shower flow restrictors.
   c. Insulate your water heater.
   d. Set the water heater thermostat at a lower temperature, if possible
   e. Take showers instead of baths.

f. Take cooler showers and make them short.
g. Try washing clothes with cold water

Discuss these with other members of your group and with your parents. Check your own home for compliance.

2. List the advantages and disadvantages of the following kinds of water heaters (if you do not know how they work, find out):
   a. electric water heater
   b. gas water heater
   c. heat pump water heater
   d. simple solar preheater for water (water runs through a garden hose inside a solar collector box before filling the water heater)
   e. solar water heater

3. If an electric water heater uses 5,400 kilowatthours annually and a natural gas water heater uses 25,000 cubic feet of natural gas, determine how much each will cost to run annually. Your local gas and electric utilities can help you.

4. Select a water heater for a new home and explain your choice.

ENERGY-EFFICIENT STRUCTURES

Activity 11: Energy Waste Management

Managing energy use and waste in the home can be a difficult subject to understand. Three important elements of energy waste management are preheating, heat exchanging, and recycling. Although these are most commonly though of as being practical for industries, large buildings (like schools and office buildings), and other large energy consumers, homeowners can benefit from energy waste management, too. From your personal knowledge, answer the following questions. Afterwards, at home or in the library, gather additional information for your presentation.

1. There are a few uses of preheating in the home. One example is a passive solar water heater that preheats water before filling the water heater with it. Another example is taking frozen food from the freezer and letting it thaw on its own before cooking it, this saves cooking time and energy. Can you think of any other examples of preheating?

2. A heat exchanger is a device by which heat is transferred from one material or fluid to another. For example, an automobile radiator is a heat exchanger by which a water/antifreeze mixture, used to cool the engine, loses waste engine heat to outside air forced through radiator passages. The water is cooled for re-use by outside air. However, most of the heat picked up by the outside air is not used. How does the automobile use some of it?

3. Are there heat exchangers in the house? How does the air conditioner cool household air? How does the heat pump heat inside air? What other heat exchange applications in the home

can you list?

4. List materials used in or around the home that can be recycled. List materials found in your garbage can which can be recycled

5. Would you recommend any energy waste management systems for a new home? Rate their costs by using the following comparisons: (a) How would the systems compare in cost to a central heating and cooling system? (b) How would they compare in cost to a refrigerator? (c) How would they compare in cost to a water heater?

Source: Tennessee Valley Authority, Energy Sourcebook: High School Unit