Renewable Energy Guide for Buildings

RENEWABLE ENERGY
THE INFINITE POWER
OF TEXAS

For High School

OVERVIEW

This unit provides students with information about the actions a builder or homeowner can take to increase heating and cooling efficiency of a home while reducing dependency on nonrenewable sources of energy. Differences in insulation materials and their heat conductive properties will be compared in the laboratory activity. Conserving valuable energy by improving R-values for insulation in each residential and commercial building is a point to emphasize. After completing this unit, students will be more knowledgeable consumers regarding energy efficiency and passive solar, photovoltaics and wind power options.

OBJECTIVES

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

SUGGESTED TIMEFRAME

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

Time	Activity Description	Content Area
60 minutes	**1** – Introduction and Reading Passage	Science Vocabulary Reading
120 minutes over two consecutive periods	**2** – Lab Activity – Testing Insulation Materials	Science Mathematics
30 minutes	**3** – Assessment	Science Mathematics Reading
60 minutes over two class periods several weeks apart	**4** – Follow Up Lab Activity – “Shady” Windows	Science Mathematics Vocabulary

REQUIRED MATERIALS

- copy of the Reading Passage and Student Data Sheets for each student
- a Lab Activity equipment kit for each group containing:
  - 2 Dixie cups (small bathroom dispenser size, plastic or waxed finish) per test material
  - water
  - access to a freezer
  - graduated cylinder (10 or 25 ml size range) per test material
  - packaging tape
  - miscellaneous insulating materials to test (commercial insulation pieces, Styrofoam, cotton balls or cotton batting, various fabrics, packing peanuts, paper towels, newspaper, bubble wrap, etc.) Supply some materials and have students bring some materials from home to test.
  - ruler
  - marker
  - stapler
  - goggles
- a Follow Up Lab equipment kit for each group containing:
  - ruler
  - marker
  - protractor
  - toilet plunger (to be used as gnomon)
  - pencil
  - poster paper

BACKGROUND INFORMATION

The proper design, construction, and maintenance of buildings can have a significant, positive impact on our environment and our natural resources. According to the U.S. Department of Energy there are over 76 million residential buildings and nearly 5 million commercial buildings in the U.S. today. Together, these buildings use one-third of all the energy and two-thirds of all electricity consumed in the U.S. By 2010, another 38 million buildings will be constructed. The challenge will be to use construction techniques and building design that minimize use of nonrenewable energy, reduce pollution, and reduce overall energy costs, while maintaining or increasing the comfort, health, and safety of the people who live and work in these buildings. For example, if only 10 percent of homes in the U.S. used solar water-heating systems to supply most of their hot water needs, we could eliminate 8.4 million metric tons of carbon emissions each year.

Designing a building to incorporate renewable energy sources is less expensive than retrofitting and allows the cost to be amortized over the term of the mortgage. Amortization of the cost of renewable energy systems will become even more attractive as the already reliable renewable energy systems become even more reliable. Another way to conserve energy, reduce energy costs, and preserve desired comfort levels is to design and build homes and businesses that are more energy efficient through better insulation and weatherproofing. This approach to building design is known as "green" building, although the principles of green building design also include reducing indoor and outdoor air pollution, conserving energy during construction, using recycled and recyclable materials, and other factors.

SUMMARY OF ACTIVITIES

Activity 1 – Introduction and Reading Passage

Teachers should read the entire sequence of activities first, before starting the lab. Explain to the class that they will learn about one aspect of "green" building design, using sufficient insulation. Have students consider the following quote:

"The concept is interesting and well-formed, but in order to earn better than a 'C,' the idea must be feasible." – *A Yale University management professor in response to Fred Smith's paper proposing reliable overnight delivery service. Smith went on to found FedEx.*

Ask students what ideas they might have to make buildings more energy efficient, and what must be feasible about those ideas. What would be necessary to make them work? What things would have to be considered? Have them brainstorm about solar energy, wind power, biomass, and materials used in construction. Ask students to consider costs, benefits, and overall feasibility as they relate to topics discussed. Teachers can also include material from the teacher background information section.

Each student will need a copy of the Reading Passage and the Student Data Sheets (includes reading comprehension questions, vocabulary words and Lab Activity). Instruct students to study the Reading Passage, "Renewable Energy Guide for Buildings," and also complete the Student Data Sheet to help them understand the role of good building design in reducing our dependence on non-renewable sources of energy. Key vocabulary words in the Reading Passage will assist them in understanding the Lab Activity instructions. For students who wish to learn more of the physics principles of heat transfer, any high school physics textbook will be helpful. For information about passive solar energy and "green" building design, direct them to the appropriate resources. Suggested resources are included in the Teacher Resource Guide. Appropriate safety guidelines should also be reviewed.

Activity 2 – Lab Activity – Testing Insulation

1. Students will study the insulating ability of various materials by measuring how much liquid water collects as ice melts in a fixed amount of time.

   The number of cups used in the Lab Activity depends on the amount of available freezer space. The instructions included in the Student Data Sheet for the Lab Activity begin with having the students prepare the cups to be frozen, as well as their test cups. Optionally, the teacher may prefer to prepare all the frozen cups in advance. Student groups should test at least three different insulation materials. They should attempt to layer each test material as close to the recommended 1" thickness as possible. The thickness may need to be adjusted, depending upon materials gathered (size of packing peanuts, for instance), but should remain consistent for all 3 materials. They will also test 3 different thicknesses of one of their materials. So students will need at least 6 cups of ice and 6 insulating cups for a total of 12 cups per group. Students can also bring in materials advertised in home improvement stores and discuss advertising claims. Materials could include fabrics, outdoor camping materials and commercial building insulation.

2. Inform students of the number of cups they will test (as determined by the teacher). The cups filled with water can be stacked in the freezer on trays. For each cup of frozen liquid, the lab group needs 1 cup prepared with insulating material.

   Placing the cups in the sunlight is the best arrangement because it simulates solar energy; however, heat lamps or even ordinary desk lamps can be used. If an electrical heat source is being used, pretest the distance of the source away from the cups to be sure the ice does not melt artificially fast and advise the students of that distance. The smaller the amount of melted liquid produced, the better is the insulation.

   Students should compile their data for the type of material used, thickness of material and amount of liquid collected. Construct a bar graph for the 3 different materials and a scatter plot for the 3 different thicknesses.

3. Distribute copies of the Lab Activity to each student but have students work in groups (as determined by the teacher). Before beginning the lab, students should review the instructions so they will understand the purpose and the goals. To enhance the class' scientific inquiry in this lab, instruct each student to develop statements for the following: hypothesis, predictions, conclusions and finally significance/implications. Note that the hypothesis and predictions should be made before beginning the Lab Activity. Refer to the Teacher Resource Guide for more information. Ask students to obtain a materials kit. Students should record the time and amount of water collected in the tables provided in the Lab Activity. After students have completed their Data Tables, students should answer the data analysis questions listed in the Lab Activity.

Expected Observations

Students should observe distinct and significant differences between the various kinds of insulation. As a general rule, thicker insulation will retard heat flow better than thinner insulation. Insulation with a lot of air trapped in closed cells is the best.

Activity 3 – Assessment

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

Activity 4 – Follow Up Lab – "Shady" Windows

The Follow Up Lab allows students to investigate one form of passive solar heating, using awnings or overhangs to shade windows in the summer or to let sunlight in during the winter. The students measure the altitude of the sun near noon to see how it can be simply done. (Local noon differs from clock noon, because of time zones.) Make at least one measurement of sun angle within a week of the December solstice (December 21) to determine the winter angle. You can also determine the maximum altitude of the sun for every month using planetarium software or by going to the United States Naval Observatory website: http://aa.usno.navy.mil/data/docs/AltAz.html.

If students do not have access to either planetarium software or access to the Internet, prepare data tables of the noon solar altitude at your latitude in advance by pointing your browser to the website above and entering your location and the date. The software will display a list. Pick the point closest to an azimuth of 180 degrees and record the time and altitude. Obtain at least 12 different data points each a month apart, including the two solstices. Students will be asked to make simple trigonometry calculations. If these are unfamiliar to the class, provide a brief summary.

Engage the class in a discussion of the topics from the Follow Up Lab Introduction in between sun angle readings over the one hour period of time.

Note: If you choose to have students actually measure the altitude of the sun on two different days during the semester, make the first measurement as early in a semester as possible and the second measurement as late in the same semester as possible.

ADDITIONAL ACTIVITY

1 – Testing Insulation Lab Extension

Repeat the main Lab Activity using hot water instead of ice water. Use cups designed to hold hot liquids as not all are capable of it. Students should insulate the cups using the same materials in the main Lab Activity. Instead of recording the amount of ice melted, students should use a thermometer and measure the temperature at the noted time intervals. Students can create new Data Tables on separate pieces of paper and should replace the measured variable to temperature. Students should also take an initial temperature reading as soon as the hot water is poured into the cup. This activity can lead to a discussion about effectiveness of materials used to insulate from the cold such as for a water heater or for keeping a house warmer in the winter. Ask students if those insulators that keep things cool are also as effective in keeping them warm.

2 – Internet or Library Research

a. Students and teachers can learn about the move toward green building design in public school facilities. Some useful Internet sites as of 2005 include:

http://www.mcps.k12.md.us/departments/facilities/greenschoolsfocus/new-school-design.htm
http://www.acps.k12.va.us/news2003/nr041003.php
http://www.nesea.org/buildings/greenschoolsresources.html

b. Instruct students to gather information on the best home insulating materials using commercial information, builders' guides and the Internet. Students can create a chart listing the types of insulating materials, costs and insulation values (R-value) and present their findings to the class or submit as an assignment. Suggested web sites include: www.homepower.com; www.greenbuilder.com. Students should find materials such as blown cellulose (recycled newspapers), polystyrene, polyurethane, fiberglass and a host of other materials that are used commercially to insulate.

3 – Energy Rebates In Your Area

Often utility companies will compensate their customers for using more energy-wise components or renewable energy equipment in the home. Instruct students to use the Internet or make phone calls to see what efficiency and/or renewable energy rebates or other incentives are being offered in their area.

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HIGHLIGHTS

- **Insulation and efficient appliances reduce energy needs**
- **Passive and active solar applications provide cost-effective solutions**
- **Take advantage of Texas breezes**

RENEWABLE RESOURCE CHECKLIST FOR BUILDINGS

- ◆ **Encourage designs that shade the structure to avoid after-the-fact fixes like solar screens.**
- ◆ **Encourage design "buffers" on west walls (like garages and closets) to reduce the impact of afternoon summer sun. Sometimes this is as easy as flipping the elevation so the garage is on the west side.**
- ◆ **Minimize carpet area and make use of the thermal mass of tile and finished concrete floors.**
- ◆ **Install windows rated by the National Fenestration Rating Council and optimize the climate appropriate window to square footage ratio.**
- ◆ **Ensure that window placement allows flow-through ventilation, both from prevailing breezes, and by low and high windows that draw air through the house.**
- ◆ **Optimize insulation levels.**
- ◆ **Install or encourage high-efficiency appliances.**
- ◆ **Minimize electrical needs.**
- ◆ **Reduce hot water needs with water conservation.**

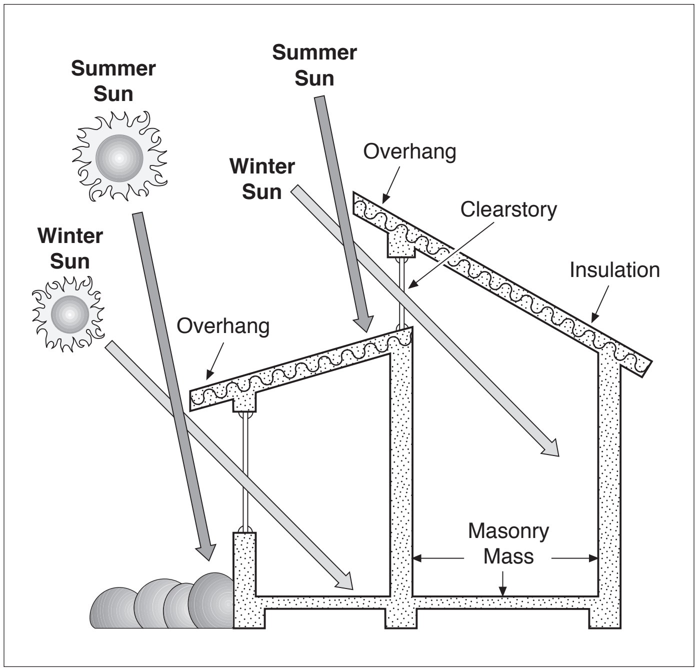
INTRODUCTION

Builders and future homeowners can easily take advantage of renewable energy sources if they incorporate them in their initial plans. Solar water heaters, photovoltaic systems, passive solar heating and other techniques can be employed by builders who desire a cost-effective and comfortable living space.

INSULATION, WINDOWS AND EFFICIENCY

A home that uses renewable energy should first be energy efficient. The best-laid energy plans will have little effect if a house is not properly insulated, installing at least R-30 in the ceilings and R-13 in the walls. Radiant barriers, proper duct sealing, high performance windows and other relatively low cost measures will also make a home more livable and efficient.

Windows can improve the thermal performance of homes by minimizing heat loss in heating-dominated climates and by minimizing solar heat gain in cooling-dominated climates. In climates with both heating and cooling seasons, select windows with both low U-values and low solar heat gain coefficiency (SHGC). SHGC is



NATURAL HEATING & COOLING OF THE HOME *Low winter sun through south-facing windows helps heat the home in the winter. Overhangs keep the high summer sun out, while still allowing indirect lighting.*

a measure of the amount of solar energy that a glazing material allows to pass. Further south, the SHGC becomes more critical.

Appliances, particularly the refrigerator, washer and dryer, can consume huge amounts of energy. Select horizontal-axis washing machines that conserve water and the energy to heat it. When you do shop for an appliance look for the ENERGY STAR label.

SOLAR ENERGY

Passive Solar

The location and orientation of the home on the site are the first and most critical steps to take advantage of passive solar gains and breezes. While the ideal site is not always available, you can make changes to the building form to fit the site. In our hot climate, it is best to look for ways to minimize living areas with large windows that face west in order to minimize heat gain from the sun. If possible orient the home to face south. Locate rooms like the kitchen or game rooms to take advantage of day lighting. Leave vegetation and add overhangs to windows that have an east or west exposure. Consider "dog-trots," or breezeways, to help collect wind and provide cooling to the building. Use materials that reflect the summer heat like a metal roof that can also be used to collect rainwater.

Day Lighting

The sun not only provides the best light, it's free. Despite these facts, day lighting is rarely discussed when talking about energy needs in the home. Well-placed windows that allow indirect light decrease the amount of electricity needed for general and task lighting.

Solar Water/Space Heating

While this option requires a higher initial outlay than gas or electric water heaters, solar water heaters are cost-effective. Solar panels can be used to pre-heat the water. Then, a small gas or electric heater is used to bring the water up to the desired temperature.

Solar water heaters can also be coupled with heat exchangers to heat the home. These systems usually rely on a large tank of water or other material that has been heated by the sun. That heat source is used to warm air that is then circulated throughout the home. While these systems can be more complex than conventional heating systems, their fuel requirements can be significantly reduced by replacing gas or electricity with solar heat.

Solar water heating is particularly attractive in homes with swimming pools. Depending on the location, solar pool heaters cost from $2,000 to $5,000 installed and can pay for themselves in 2 to 7 years by replacing conventional forms of energy with heat from the sun.

Solar Electric Power

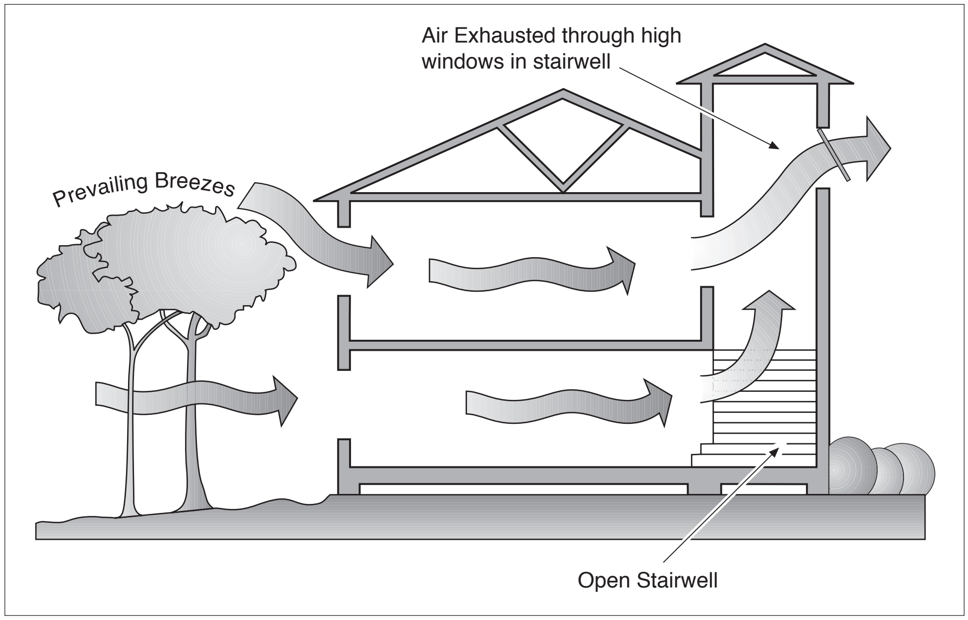
While the cost of photovoltaic (PV) cells continues to drop, the practicality of meeting all or most of the homes' electrical needs with solar is still limited.

Innovations continue to emerge, like roofing material made of PV cells, but lower cost options, including solar-powered gate openers, outdoor lighting and water pumps, can pay for themselves in a short time.

WIND POWER

Wind power was always considered a priority on farms and ranches before rural electrification because it was the primary method for pumping water. In many areas of Texas, small wind generators can compete with (and even beat) local electric rates for providing the home's electricity.

While relatively few new homes rely on wind power, homeowners can take advantage of the wind for cooling if they locate their home perpendicular to the prevailing wind. Window style (i.e. double-hung and casement windows), window placement and home design must allow flow-through ventilation, both from prevailing breezes, and by low and high windows that draw air through the house.



CREATING A THERMAL CHIMNEY *A thermal chimney is designed to cool using the natural tendency of warm air to rise. Air is warmed by the sun in a stairwell, and as it exits through windows at the top, cooler air is drawn through the home.*

SOURCE: SUSTAINABLE LIVING ALLIANCE

USING RENEWABLE ENERGY FOR YOUR HOME *This Central Texas "Cool" house uses passive solar design with a reflective roof, radiant barrier, overhangs, thermal chimney with operable windows, stained concrete floors and optimal wall and ceiling insulation.*

Understanding the Reading Passage

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

1. List two reasons why builders and architects should design homes to use renewable energy.

    1 ______________________________

    2 ______________________________

2. What is the function of insulation?

    ____

    ____

3. What is the least expensive form of indoor lighting? ______________________________

4. Why should homes be designed to face north and south, with most windows on the south-facing side?

    ____

    ____

5. What three forms of solar energy are already available for homes?

    1 ______________________________

    2 ______________________________

    3 ______________________________

6. Describe how a thermal chimney works.

    ____

    ____

Vocabulary

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

casement window ______________________________

daylighting ______________________________

design “buffer” ______________________________

double-hung window ______________________________

flow-through ventilation ______________________________

masonry ______________________________

orientation ______________________________

overhang ______________________________

power grid ______________________________

radiant barrier ______________________________

R –Value ______________________________

SHGC (solar heat gain coefficiency) ______________________________

thermal chimney ______________________________

thermal mass ______________________________

U-value ______________________________

LAB ACTIVITY – TESTING INSULATION MATERIALS

INTRODUCTION

The purpose of this activity is to determine the effectiveness of various kinds of materials used as insulation. Insulation plays a vital role in reducing wasted energy in a properly designed house.

BEFORE YOU START

Review the vocabulary words from the Reading Passage. Ask your teacher if you are unsure of any of the meanings.

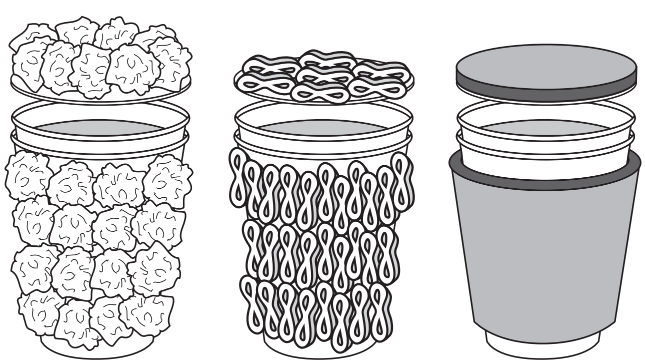
MATERIALS

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

- 2 Dixie cups per test material
- water
- a freezer
- graduated cylinder (10 or 25 ml size range) per test material
- packaging tape
- miscellaneous insulating materials to test (commercial insulation pieces, Styrofoam, cotton balls or batting, fabrics, packing peanuts, paper towels, newspaper, bubble wrap, etc.) You can bring some materials from home to test.
- ruler
- poster board
- marker
- stapler
- goggles

Step 1. Preparation (wear goggles)

1. Take half of the Dixie cups you are instructed to use by your teacher and make a mark 1 cm below the top edge of each cup using a marker. Label each of your cups with your group name or number
2. Fill the cup(s) to the 1 cm mark with cool water.
3. As the teacher instructs, place your cup(s) on a tray to be placed in the freezer.
4. Use the remaining half of the cups to design and construct insulated containers with the materials you choose to use for insulation. Use one of the cups as a template to draw a number of circles on the poster paper equal to the number of cups in the freezer. Carefully cut out each of the circles. The insulated container you design will hold the frozen Dixie cups. The poster paper circles will become lids for the insulating containers.
5. Choose your insulating materials, which will vary by group. You will also be testing one of the insulating materials in 3 varying degrees of thickness for comparison.
6. Wrap 1" of one the insulating materials around one container and tape or staple the materials in place. If you are using stiff Styrofoam, you will have to cut it in thin strips to fit around the circular cup. The packing peanuts may best be stuck to tape first and then secure the tape to the cup. Also cover the lid. Use tape sparingly, as it will add to your insulation and affect your results. Repeat this step with the other insulating materials being tested. Label each cup with your group name or number and assign numbers to each cup. Record the materials being used on Data Table 1.
7. Choose one test material and prepare 3 cups in the same manner as Step 6, except you will use 3 different measures of thickness. Record the measures of thickness on Data Table 2.
8. Store your labeled "designer insulated cups" as instructed.



Step 2. Performing the Activity (wear goggles)

1. Place your prepared "designer insulated cups" with the 3 different test materials on the lab table.
2. Obtain the frozen cups prepared beforehand.
3. Place each frozen cup into a "designer insulated cup" and immediately place the cover on top. Do this for each of your designer cups.
4. Place your "designer insulated cups" with the frozen cup inside in the sunlight, if possible, or as instructed by your teacher. Record the time.
5. Every 4 minutes, uncover your insulated design and carefully pour out any melted water into a graduated cylinder, being sure to keep the remaining ice in the cup. Re-cover immediately and return the cup to the sunlight. Repeat for each of your insulated cups. A unique graduated cylinder should be used for each type of test material to keep each measurement separate.
6. On Data Table 1 record the amount of water melted by the designer insulated cup in a total of 20 minutes. (Do this for each different designer insulated cup you are testing.)
7. Repeat Steps 1 - 5 with the 3 cups of one material in 3 different thicknesses. On Data Table 2 record the amount of water melted by the insulated cups in a total of 20 minutes.
8. Complete your Data Tables and share your information as instructed by your teacher, so that a bar graph can be constructed showing the amounts of melted water for the various kinds of materials used. (The least amount of melted liquid indicates the best insulator.)
9. Construct a scatter plot (*x-y* graph) of the amount of water melted versus thickness. Thickness is the independent variable so it goes on the *x*-axis.

STUDENT DATA SHEET

DATA TABLE 1. Amount of ice melted by type of insulating material

Cup #:	1	2	3
Type of insulating material			
Time Interval (minutes)	Amount of ice melted	Amount of ice melted	Amount of ice melted
4			
8			
12			
16			
20			

DATA TABLE 2. Amount of ice melted by thickness of insulating material

Insulating Material:			
Cup #:	1	2	3
Thickness of insulating material:			
Time Interval (minutes)	Amount of ice melted	Amount of ice melted	Amount of ice melted
4			
8			
12			
16			
20			

DATA SUMMARY

1. Which material was the best insulator? ______________________________

2. Did the thickness of material make any difference? ____________ If so, what was the difference?

____

Assessment Questions

1. Using your own home or a relative's home as an example, list things that could be done in order to make it more energy efficient. Be specific about what materials you would use, and how and where you would place them.

2. Why are high performance windows beneficial?

3. If you are building a home in Texas, in which directions should you pay special attention to the amount of window area?

4. If you were building a new home, write a paragraph about how you would design it to conserve energy. Include a drawing of your home, like that in the Reading Passage, that illustrates your design.

Multiple Choice Questions

1. For energy efficiency, in placement of windows, one should consider:
   a) air flow through house
   b) seasonal changes in sun's angles
   c) summer indirect lighting
   d) all answers a, b, and c

2. In winter the sun's radiance on south facing windows is:
   a) at a lower angle
   b) at a higher angle
   c) the same as in summer
   d) shifted to north

3. Which flooring takes the most advantage of thermal mass?
   a) carpeting
   b) astro turf
   c) vinyl
   d) tile

4. Insulation should be installed:
   a) in ceilings
   b) in walls
   c) around windows
   d) all answers a, b, and c

5. Which statement is true?
   a) all appliances have the same energy cost per minute
   b) the direction a house faces has no effect on its energy costs
   c) many windows should be constructed on the north side of a home
   d) money can be saved if windows, house placement, and design are planned for solar heating and cooling

6. A thermal chimney:
   a) burns only gas logs
   b) allows hot air to escape
   c) is a turbine
   d) includes a 2 sided fireplace through high windows

7. By incorporating renewable energy sources in their plans, builders can use:
   a) solar water heating systems
   b) photovoltaic systems
   c) passive solar heating
   d) all answers a, b, and c

8. When you build your home, which R-Value would provide the best insulation in your ceilings?
   a) R = 10
   b) R = 30
   c) R = 5
   d) R = 15

9. In purchasing your dryer, washing machine, oven or other appliance, an important factor to consider for operating cost is:
   a) color
   b) number of button options, shape
   c) its tested energy efficiency
   d) programming choices

10. Learning about how to have a more energy efficient home:
    a) could help you in the future
    b) is not important
    c) could save you money
    d) answers a and c

FOLLOW UP ACTIVITY – "SHADY" WINDOWS

INTRODUCTION

Many people think the sun rises due east, goes directly overhead, and sets due west. When asked to explain why Earth has seasons, people often construct a mental model based on Earth's distance from the sun. However, the variation in the distance of Earth from the sun is far too small to account for the variation in temperature. Furthermore, if distance from the sun were the cause of Earth's seasons, then it would be winter at the same time all over Earth. That is not the case. When it is winter in Texas, it is summer in Australia. Instead, it is the 23.45-degree tilt of our planet's rotational axis that causes us to have winter and summer.

In Texas, the winter sun rises in the southeast and passes low across the southern sky to set in the southwest. Windows on the south side of the house can let in the winter sun to warm the house when the outside air is cool. However, south-facing windows must be shaded from the summer sun. In the summer, the sun is much higher in the southern sky. It rises in the northeast, passes just to the south of directly overhead at midday, and sets in the northwest.

A passive solar house in Texas can be designed to take advantage of the varying angle of the sun. North-facing windows should be well sealed against wind and probably double-glazed. East-facing windows can be situated to let in the morning sun. West-facing windows can be minimized or eliminated to block the low rays from the setting sun. South-facing windows can be shaded by deciduous trees or with awnings or roof overhangs that block the summer sun but allow winter sunlight in to warm the house.

On an existing house, it is generally easier and cheaper to install awnings. When a new house is built, overhangs can be incorporated into the design. How big should the awning or overhang be? That depends on the location of the house. If the house is situated far to the north (for example, in Minnesota) the overhang may be impractically wide. Texas is ideally located to benefit from this form of passive solar heating.

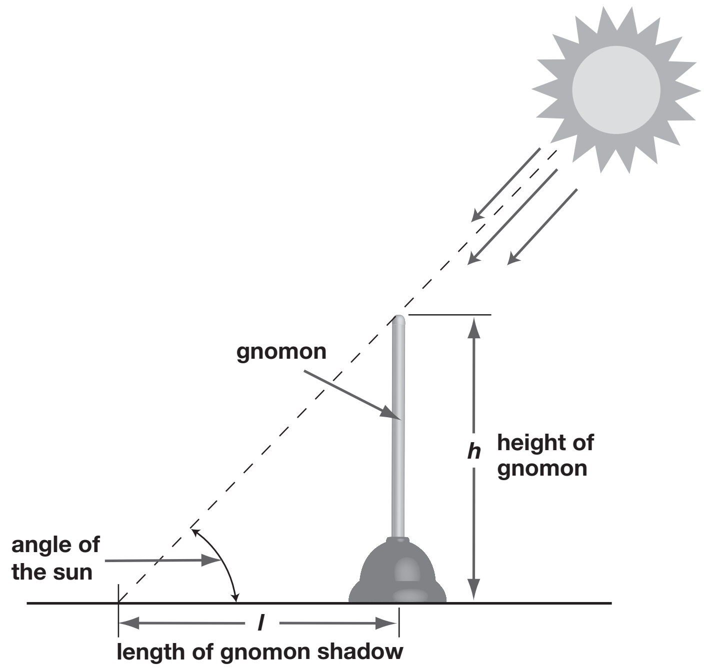
In this activity, students will determine the variation in noon altitude of the sun and design an overhang or shade so that south-facing windows are shaded in summer but receive sunlight in winter.

MATERIALS

- ruler
- marker
- protractor
- toilet plunger (to be used as gnomon)
- pencil
- poster paper

Step I. Measuring the Altitude of the Sun

1. About 30 minutes before noon (standard time), take the poster paper, protractor, directional compass, meter stick and your gnomon outside.



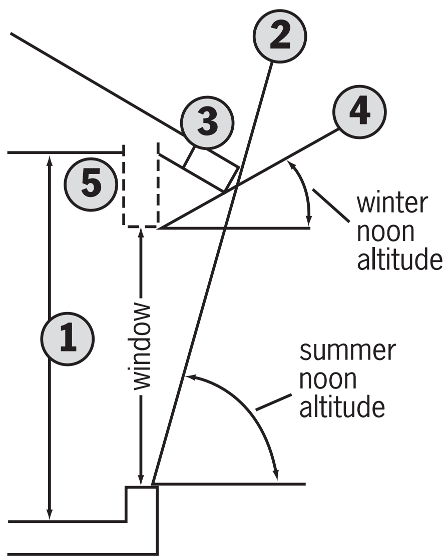
2. Use the compass to locate north. Place the poster paper flat on the ground in a level, smooth, and sunny location so that the long side is oriented north and south. Use tape or small weights to hold the paper in place.
3. Set the gnomon at the south edge of the poster paper and mark the locations of the base of the gnomon and the tip of the shadow of the gnomon. Label the shadow of the tip with the time.
4. Every 15 minutes mark the new position of the tip of the gnomon and label it with the time.
5. Continue until 30 minutes after noon. You will have marked five points.
6. Draw a smooth curve through all five points.
7. Return to the classroom and find the point on the curve you have drawn that is closest to the gnomon. Estimate the time this occurred. This time is called local noon.
8. Draw a line from the point of local noon to the center of the base of the gnomon. This line should be true north and south.
9. Measure the length of the shadow, l, at local noon and the height of the gnomon, h.
10. Determine the altitude of the sun: $altitude = \tan^{-1}\left(\frac{h}{l}\right)$
11. Repeat after an interval of several weeks.

Step II. Daily Variation of Solar Altitude

1. On your computer, start your web browser and point it to: http://aa.usno.navy.mil/data/docs/AltAz.html
2. Enter your location and select the date as January 21.
3. Scan the list that is produced and pick the time and altitude closest to an azimuth of 180°. This time should be approximately the same as your calculation of local noon and the altitude should be a maximum.
4. Record the date and the maximum altitude.
5. Repeat for each month through December 21.
6. Construct a graph of the maximum altitude of the sun versus the date.
7. Draw a smooth curve through the monthly solar altitude points.
8. From the graph you just drew, read the seasonal maximum noon altitude of the sun and the seasonal minimum noon altitude and the dates on which those occur.

Step III. Constructing the Scale Model of the Wall

1. Make a scale drawing of the window to be shaded on your poster board. Include a roof with an appropriate slant.
2. Starting at the bottom of the window, draw a line upward at the angle of the maximum noon altitude of the summer sun.
3. Draw an overhang that just touches the line drawn in step 2.
4. Draw a line from the edge of the overhang to the wall at the angle of the minimum noon altitude of the winter sun.
5. The wall will be solid above the point where the line intersects the wall in step 4. The window occupies the rest of the space between where the two lines to the sun intersect the wall.



DATA SUMMARY

1. What was the maximum summer altitude of the sun? ______________________________
2. On what day did the maximum summer altitude occur? ______________________________
3. What was the minimum winter altitude of the sun? ______________________________
4. On what day minimum winter altitude occur? ______________________________
5. What is the height of your window? ______________________________

TEACHER ANSWER KEY

Understanding the Reading Passage

1. It is cheaper to design the features into the home than it is to retrofit existing homes. Proper design conserves energy and reduces dependence on non-renewable energy.
2. Insulation retards the flow of heat.
3. day lighting
4. Homes should be oriented to receive the maximum benefit from sunlight in winter, but to block sunlight from entering the home in summer. West facing windows should be minimized to block the rays from the setting sun. In cold climates, north facing windows should be minimized or well sealed to block cold north winds.
5. day lighting, solar water heaters, solar space heating, passive design and solar electric power
6. Sunlight warms the air in the thermal chimney. The warm air rises in the chimney, drawing in cool air through lower, open windows.

Lab Activity Data Summary

1. Answers will vary based on the material.
2. The thickness of the material used should have made a significant difference in insulating characteristics.

Assessment Questions

1. Among many measures to choose are sealing air leaks, especially around windows and doors, installing better insulation, using passive solar heat, accommodating flow of breezes, as well as venting hot air in the summer.
2. High performance windows improve the thermal performance of the home by minimizing heat loss in colder climates and minimizing solar heat gain in hotter climates.
3. south and west
4. Students should incorporate some of the concepts presented in the unit.

Multiple Choice Questions

1 d; 2 a; 3 d; 4 d; 5 d; 6 b; 7 d; 8 b; 9 c; 10 d

Vocabulary Definitions

casement window – a window with hinges on one of the vertical sides that swings open like a normal door

day lighting – using natural light to provide lighting for interior spaces, such as well-placed windows

design "buffer" – a space designed into the west wall of a building, such as a garage, closets or a large overhang, to reduce the effect of the hot afternoon sun

double-hung window – a window with two vertically sliding sashes (or frames), both of which can move up and down

flow-through ventilation – window positions on opposite walls to capture the breezes for better cooling

masonry – building in stone; stonework used in construction

orientation – the position of a building (home) relative to the points of the compass (north, south, east, west); the south facing side is critical regarding window placement

overhang – a solid horizontal or angled roof section that extends significantly beyond the house walls, built so it shades windows on the south side in summer, but allows sunlight to enter in winter

power grid – a network of high voltage transmission lines distributing electrical power throughout a region

radiant barrier – a shiny reflective material usually applied to the underside of the roof to reduce the attic temperature by preventing heat from entering

R-value – numerical scale for insulation value (R-6 is a low value; R-30 is a high value)

SHGC (solar heat gain coefficiency) – a measure of the amount of solar energy that a glazing material allows to pass

thermal chimney – a building design element that takes advantage of warm air rising by planning an exit for warm air that then draws cooler air in

thermal mass – a dense material that gains or loses heat slowly, such as concrete, adobe, stone, brick, tile and water

U-value – a measure of the rate of heat loss or gain through a material; the lower the U-factor, the greater the material's resistance to heat flow and the better its insulating value (U-value is the inverse of R-value)

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