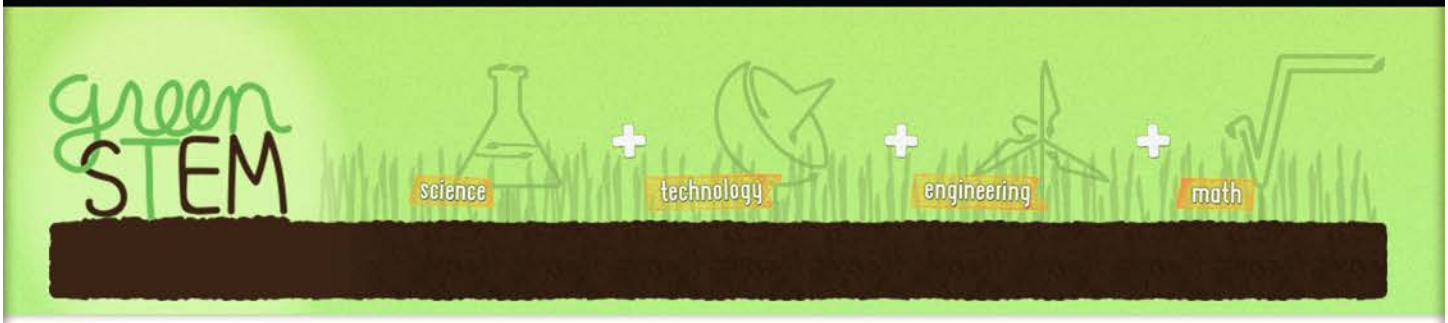

Getting Warmer: Solar Water Heaters

Grade Levels: 6 – 12

Objective: To investigate solar energy technology by building model solar water heater s that mimic full-scale units in residences to capture energy in the form of solar radiation and convert it to thermal energy. Students will calculate the efficiency of their model and compare designs.

Standards:

National Science Education Standards

Unifying Concepts & Processes; Standard A - Science as Inquiry; Standard B - Physical Science; Standard E - Science & Technology; Standard F - Science in Personal and Social Perspectives; Standard G – History and Nature of Science

National Council of Teachers of Mathematics Standards

Numbers & Operations: 6-8; Algebra: 6-8; Measurement: 6-8; Problem Solving: 6-8; Communication: 6-8National Educational Technology Standards

National Educational Technology Standards

Standard 1 - Creativity and Innovation; Standard 3 - Research and Information Fluency; Standard 4 - Critical Thinking, Problem Solving, and Decision Making

Virginia Standards of Learning

Science: 6.1, 6.2, 6.9, PS.1, PS.6, PS.7, E.S.1, ES.6, ES.12

Mathematics: 6.6, 6.7, 6.10, 6.14, 7.3, 7.4, 7.12, 7.14, 8.3, 8.13

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Maryland State Curriculum (Grade 6-8)

Science: 1A, 1B, 1C, 1D, 5B, 5C, 6A

Mathematics: 1.B, 4.A, 4.B

Technology Education: The Nature of Technology, The Impacts of Technology, Engineering Design and Development,

Background: Solar water heaters use energy from the sun to heat water. The water heater is made up of a collector and a storage tank. In the collector, energy from the sun is absorbed the rubber tubing in the collector and then heats the water inside the tubing through conduction. The water is pumped through the tubing to the cup which serves as the storage tank. The water that is in the cup is heated by convection. As the water continues to be pumped through the system, the temperature of the water continues to increase. In this activity, we will construct a small-scale solar water heater and measure the change In water temperature over time and calculate the heat gained by the water. We will also modify the design of the solar water heater and compare the difference in the amount of heat gained by each design.

Vocabulary:

Specific heat capacity of water: The specific heat capacity of water is the amount of heat required to raise the temperature of 1 gram (1 mL) of water by one degree Celsius.

Conduction: The transfer of heat through a substance by direct contact of atoms or molecules.

Convection: The transfer of heat by circulation of a gas or liquid.

Heat transfer: The flow of heat from one material to another. Heat always transfers from a higher temperature to a lower temperature.

Insulation: A material of low thermal conductivity used to reduce heat loss.

Materials:

For each Group:

12” x 12” x 1” Box

25 ft. Tubing (Black) 7.62 m

25 ft. Tubing (clear)

20 oz Cup

Submersible Water Pump

2V Solar Panel with Connections

Insulated electric wires with Alligator Clips on each end (jumper wires)

Thermometer

Plastic food wrap

Black paper

White paper

Aluminum Foil

Materials (continued)

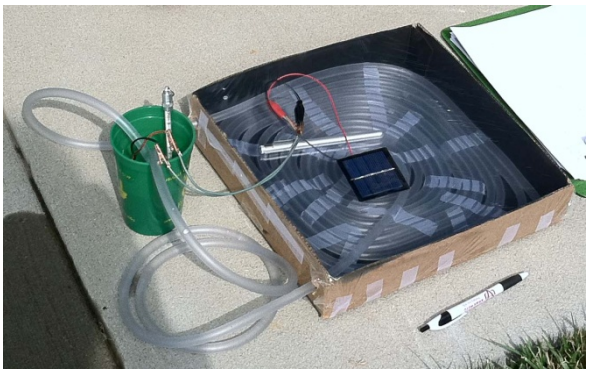
Utility Knife

Clear Packing Tape or Scotch Tape

Duct Tape

Procedure:

1. Class discussion:
    a. What is solar energy?
    b. What are some ways we use solar energy?
    c. How can we collect solar energy?
2. Constructing the solar water heater



    a. Line your box with white paper, black paper or aluminum foil. Use clear tape to hold the paper or foil in place.
    b. Using a utility knife cut small X's at either end of one side of the box. Fold the cardboard back to create a hole large enough for the tubing to pass through.
    c. Feed the tubing through one hole, leaving approximately 45 cm of tubing outside of the box.
    d. Coil the tubing inside of the box. Leave approximately 45 cm to be feed out of the box through the hole on the other end. Use clear tape to hold the coil securely inside the box.
    e. Wrap the box with the plastic wrap to cover the tubing.
    f. Insert the submersible water pump into the bottom of the cup and tape it down.
    g. Connect the positive lead (red) of the solar panel to the positive lead (red) of the water pump using a jumper wire.
    h. Connect a jumper wire to the negative lead (black) of the water pump but do not connect it to the solar panel just yet.
    i. Connect one end of the tubing onto the open end of the water pump and let the other end of the tubing rest inside the souvenir cup.

3. Experimenting with the Solar Water Heater

    a. Fill the cup with cold water.

    b. Prime the pump by sucking on the open end of the tubing until water comes out, and then place the tubing back into the cup. After priming the pump, add water to the cup to bring the level near the top. The pump must stay under water in order to function properly.

    c. Place the project box and the solar cell (photovoltaic panel) in direct sunlight (pointed towards the sun)

    d. Shade the cup using a notebook or piece of cardboard. Be careful not to spill the water in your Solar Water Heater, you will need to determine the mass of the water at the end of the experiment.

    e. Insert the thermometer into the cup of water and record the initial temperature. Keep the bulb of the thermometer in the water while reading the temperature.

    f. Connect the negative lead (black) of the water pump to the solar panel to start the pump.

    g. Record the temperature in 1-minute increments for 15 minutes on the Student Worksheet. Remember – Keep the bulb of thermometer in the water while reading the temperature.

    h. When finished unhook the negative lead of the solar panel to stop the pump.

4. Use the equation H = mCP(Tf – Ti) to calculate the heat gained by the water in the Solar Water Heater.

    H = Heat gained by water in Joules or calories

    m = mass of water in system (in kilograms)

    CP = Specific Heat of water = 4186 Joules / kg ☐C

    Tf = Final Temperature of the water at the end of the experiment

    Ti = Initial Temperature of the water at the start of the experiment

5. Compare results for different groups.

Observations & Conclusions:

1. How did the heat gained by your solar water heater compare with that of the other group?

2. What factors do you think influenced the heat gain in your solar water heater?
3. What changes would you make to the design of your solar water heater to increase the heat gain of the system?

4. What changes would you make to the placement of your solar water heater to increase the heat gain of the system?

5. If you wanted to use solar energy to heat the water in your home or school, what changes or additions would you need to make to the system?

Extensions:

1. Using the data from the entire class, have the students redesign their solar water heaters to maximize heat gain.
2. Using the internet or a weather almanac to investigate year-round weather conditions in your area, have your students develop a list of weather and seasonal factors that affect the efficiency of solar water heater in your area.
3. Invite a professional speak about how commercial solar water systems function and are used in your area and to provide the students feedback on their designs.
4. The pump in this experiment is powered by a photovoltaic cell. Have your student research photovoltaic cells and investigate hoe they function.
5. Have your class construct and experiment with Nanocrystalline dye-sensitized cells. These cells use a reaction similar to photosynthesis to produce electricity. Information about Nanocrystalline cells can be found at: http://www.solideas.com/papers/Exploratorium_Solar.pdf. Kits can be purchased at http://ice.chem.wisc.edu/Catalog/SciKits.html.

Green Jobs and Careers:

The Bureau of Labor Statistics (http://www.bls.gov/green/) defines green jobs as:

"Jobs in businesses that produce goods or provide services that benefit the environment or conserve natural resources." And "Jobs in which workers' duties involve making their establishment's production processes more environmentally friendly or use fewer natural resources."

1. Have students investigate the types of jobs are suited to their personality, skills and interests by using these online resources. The personality test center helps identify career options based on personality indicators and the O*NET tool uses interests and skills to suggest potential careers. Students can choose to use both tools and compare the results or use each tool individually.

a. Personality Career Tool Activity: Complete your Meyers Briggs type indicator at the online site.

   i. Go to www.personalitytest.net/cgi-bin/q.pl

   ii. Answer the 68 quick "either/or" questions. Choose your best answer to each question.

   iii. When you click "RESULTS" your personality type will be listed.

   iv. With your four letter reference type, choose an occupation from the list that might help suit your type and is a job that you might be interested in exploring.

   v. The listing can be found by clicking "Green Jobs List" at http://www.ctenergyeducation.com/greenjobs.htm

   vi. Do a web search of the listed resource sites and other sites to find out more about the job you chose.

      - What training/background is required?
      - What is the entry-level pay or average pay for this occupation?
      - Do there seem to be any jobs available in this occupation? If so where are they?
      - After completing your research are you more or less interested in this occupation that when you started? Explain why.

b. O*NET Interest Profiler Activity: Complete the O*NET Interest Profiler

   i. Go to http://www.mynextmove.org/explore/ip and complete the interest profiler

   ii. Answer the quick 60 questions with your best answers for each question.

   iii. When you have finished your interests will be shown in a graph, click Next to see the jobs suited to your interests.

      - Where any of the jobs you chose green jobs? If not you can go to www.onetonline.org/find/green to search the green economy jobs sector.

   iv. For the jobs listed, choose ones you are interested in.

      - What training/background is required?
      - What is the entry-level pay or average pay for this occupation?
      - Do there seem to be any jobs available in this occupation? If so where are they?
      - After completing your research are you more or less interested in this occupation that when you started? Explain why.

2. Have the students investigate green jobs related to solar energy and green building. Suggested resources:

http://www.bls.gov/green/greencareers.htm

Service-learning Projects:

Have students design a service-learning project implementing a green solution at your school or in your community.

1. Create a brochure or display explaining solar water technology and highlighting the pro and cons for use in your area. Share this information at community or PTA meeting or Earth Day celebration.
2. Develop a fun lesson for K-2 students at the school that explains Solar Energy. Have upper-grade student present this lesson to the young students in the school.
3. Work with your school administration to install solar water heaters and other solar technologies to supplement the school's traditional energy sources.
4. Work with a community organization that builds or repairs homes for the elderly, etc. install solar water heaters and other solar technology on their projects.

To learn more about service-learning visit www.servicelearning.vcu.edu and http://www.servicelearning.org/what-service-learning.

Green Jobs and Careers Extension based on an activity developed by

Rob Kincade

Mathews High School

Mathews County Public Schools

Mathews, VA

VCU VIRGINIA COMMONWEALTH UNIVERSITY Make it real.

green STEM

science + technology + engineering + math

Student Worksheet

Getting Warmer: Solar Water Heaters

Name _____

Objective: To investigate solar energy technology by building model solar water heater s that mimic full-scale units in residences to capture energy in the form of solar radiation and convert it to thermal energy. Students will calculate the heat gained by the water in their model and compare designs.

$$H = mCP(tf-Ti)$$

H = Heat gained by water in Joules or calories

m = mass of water in system (in kilograms)

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Tf = Final Temperature of the water at the end of the experiment

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1. Today's Weather

   Outside Temperature _____

   Sunny ____ Partly Cloudy ____ Cloudy ____

   Calm ____ Breezy ____ Windy ____

2. What did you line your Solar Water Heater with?

   white paper _____ black paper _____ aluminum foil _____

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3. Where did you place your solar water heater?

   Full sun _____ partial sun _____ shade _____

4. Record the water temperature for each measurement.

Time (minutes)	**Temperature** (^{o}C)		**Time** (minutes)	**Temperature** (^{o}C)
0 minutes			8 minutes	
1 minute			9 minutes	
2 minutes			10 minutes	
3 minutes			11minutes	
4minutes			12 minutes	
5 minutes			13 minutes	
6 minutes			14 minutes	
7 minutes			15 minutes	

5. Record the mass of the water in the Solar Water Heater _____ kg

6. Calculate the heat gained by the water in the Solar Water Heater:

$$H = mCP(Tf - Ti)$$

H = Heat gained by water in Joules or calories

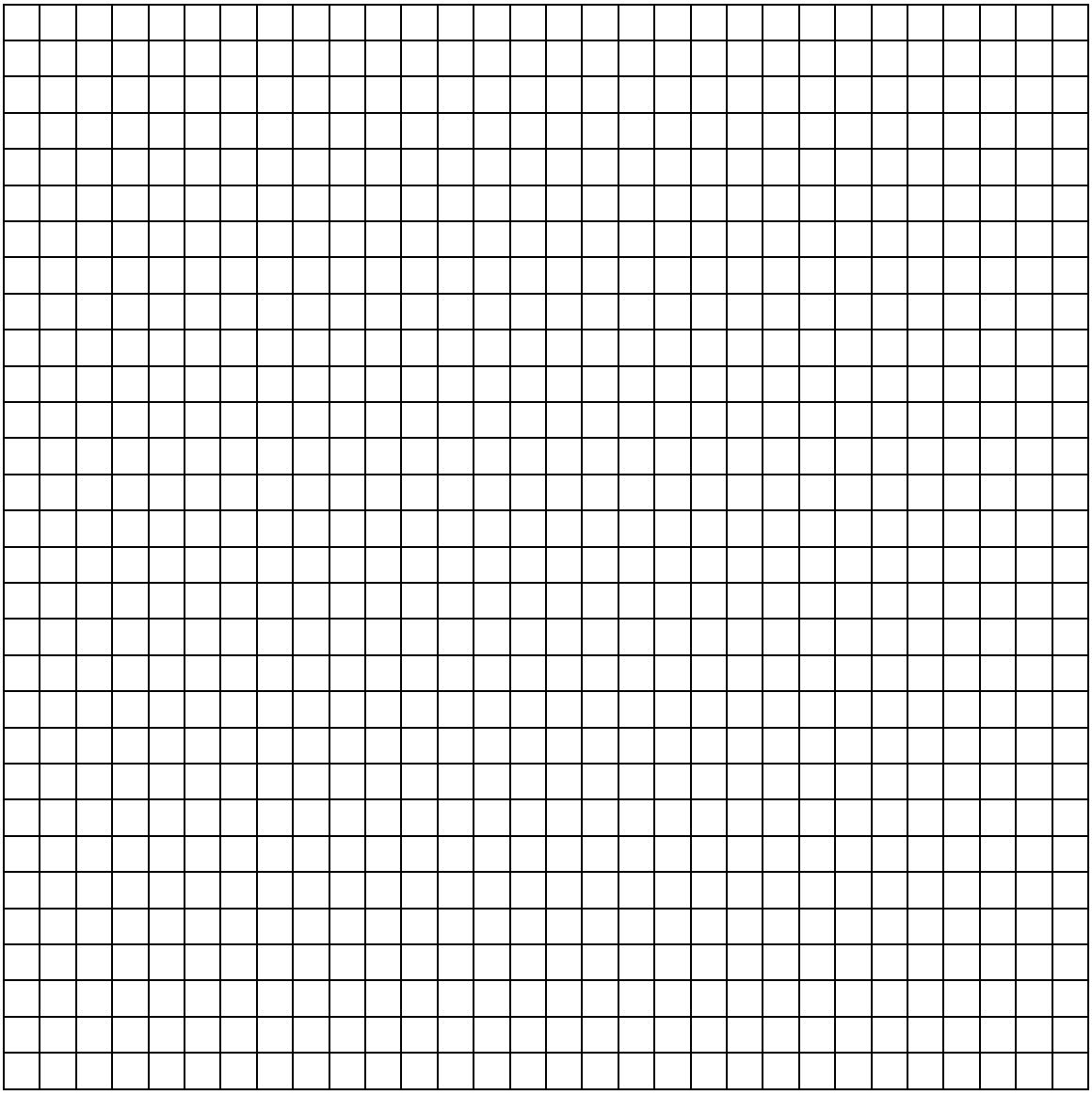
m = mass of water in system (in kilograms)

CP = Specific Heat of water = 4186 Joules / kg ☐C

Tf = Final Temperature of the water at the end of the experiment

Ti = Initial Temperature of the water at the start of the experiment

7. Create a graph showing the temperature of the water as it was warmed in the solar water heater. Use the data recorded to plot a graph of Temperature (°C) vs. Time.
(Remember to label your graph correctly.)



Observations and Conclusions:

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