

# Solar Water Heating



Design a solar water heating collector while learning heat science and building career skills

## Table of Contents

<b>Curriculum Introduction</b> .....	<b>4</b>
<b>Curriculum Key</b> .....	<b>5</b>
Setting the Stage.....	5
Activities.....	5
Assignments.....	5
Handouts.....	5
Extensions.....	5
<b>Academic Content Standards</b> .....	<b>6</b>
<b>Tool and Material Ordering Information</b> .....	<b>12</b>
Background for Lessons.....	13
Solar Water Heating Pre & Post Test.....	15
Solar Water Heating Pre & Post Test: Teacher KEY.....	18
<b>Lesson 1: Climate Change</b> .....	<b>21</b>
Preparations.....	22
Setting the Stage: The Science of Climate Change.....	24
Discussion: Historic Climate Trends.....	24
Activity 1: Strength of the Evidence.....	26
Assessment.....	28
Setting the Stage: Introduction to Environmental Justice.....	28
Discussion: Toxic Releases and Communities of Color.....	30
Activity 2: Mapping Environmental Justice.....	31
Setting the Stage: Carbon Cycle.....	33
Activity 3: Carbon Movement Through Reservoirs.....	36
Discussion: Carbon Cycle.....	36
Assessment.....	37
Setting the Stage: Atmospheric Composition and the Greenhouse Effect.....	37
Activity 4: The Greenhouse Effect.....	40
Discussion: Carbon Dioxide and Atmospheric Balance.....	42
Assessment.....	42
Assignment.....	42
Setting the Stage: Carbon Footprint.....	42
Activity 5: Carbon Footprinting.....	43
Review: Climate Change Causes, Consequences, & Opportunities.....	44

Assessment.....	46
Handout: Strength of the Evidence Graphs .....	47
Handout: Strength of the Evidence worksheet.....	52
Handout: Strength of the Evidence Research Guide .....	54
Handout: Poster Presentation Guide.....	57
Handout: Carbon Movement Through Reservoirs.....	58
Handout: Greenhouse Effect Simulation .....	60
Handout: Greenhouse Effect Simulation Teacher <b>Key</b> .....	63
<b>Lesson 2: The Science of Heat .....</b>	<b>65</b>
Key Words.....	65
Preparation.....	66
Setting the Stage: Methods of Heat Transfer .....	66
Activity 1: Conduction, Convection, and Radiation.....	67
Setting the Stage: Energy, Power, and Water Heating.....	68
Activity 2: Heating Water.....	69
Setting the Stage: Conduction and Insulation .....	71
Activity 3: Investigating Thermal Conduction and Insulation.....	72
Handout: Heating Water .....	75
Handout: Investigating Thermal Conduction and Insulation.....	77
<b>Lesson 3: Solar Water Heaters .....</b>	<b>80</b>
Key Words.....	80
Preparation.....	81
Setting the Stage: Solar Thermal Systems .....	81
Setting the Stage: Solar Radiation onto an Area.....	83
Discussion .....	83
Setting the Stage: Water Heater Efficiency.....	84
Activity 1: Water Heater Efficiency Calculations .....	85
Setting the Stage: Regulations, Rebates, and Incentives .....	86
Activity 2: Solar Water Heater Rebates and Incentives .....	87
Handout: Water Heater Efficiency Calculations.....	88
Handout: Solar Water Heating Rebates and Incentives Programs.....	90
<b>Lesson 4: Building a Solar Water Heater Collector.....</b>	<b>91</b>
Key Words.....	91
Preparation.....	92
Discussion: Insulative and Conductive Materials.....	92
Activity 1: Building a Solar Water Heater .....	93

Option 1A: Building a Cardboard Solar Water Heating Collector .....	94
Option 1B: Constructing a Wood Solar Water Heating Collector .....	99
Discussion: Efficiency of Solar Water Heaters .....	106
Activity 2: Comparing the Efficiency of the Solar Water Heaters.....	106
Handout: Building A Solar Water Heater Collector (Box Lid) .....	107
Handout: Measuring Solar Water Heater Collector Efficiency.....	108
<b>Lesson 5: Green Careers.....</b>	<b>109</b>
Key Words.....	109
Preparation.....	109
Activity 1: Exploring Green Career Pathways.....	110
Setting the Stage: Exploring Green Career Pathways .....	111
Setting the Stage: Solar Careers.....	114
Activity 2: Skills Assessment and Job Research .....	117
Assignments .....	118
Assessments .....	119
Setting the Stage: Social Media and Career Development.....	119
Setting the Stage: Applying for Jobs.....	120
Activity 3: Resume Writing & Cover Letter .....	121
Extension.....	121
Assignments .....	122
Assessments .....	123
Handout Skills Assessment Worksheet .....	124
Skills Assessment Matrix.....	125
Cover Letter and Resume Writing .....	127
Cover Letter Outline.....	129
Sample Cover Letter for Requesting an Informational Interview.....	130
Resume Outline.....	131
Sample Resume .....	132
Career Informational Interview & Shadowing Questions.....	133
Career Professional Panel .....	134



## Lesson 4 Overview

### Estimate Time:

1-4 45-minute lessons (depending on optional extension project)

### Standards:

NGSS: HS-ETS1-2, HS-ETS1-3, HS-PS3-3  
CCSS ELA: Reading Standards for Science and Technical Subjects 3  
CCSS Math: G-MG-3  
CTE Energy, Environment, and Utilities: A11.1

### Objectives:

 Students will be able to:

- Use their knowledge of materials with high thermal insulation and conduction properties to design a solar thermal collector
- Build a solar water heating collector

### Handouts:

- 4.1 Building a Solar Water Heater Collector
- 4.2 Measuring Solar Water Heater Collector Efficiency

### Prep Time:

- 1.5 hours

### Materials:

- PowerPoint presentation and projector
- Internet access
- Student decided materials for Solar Water Heater Collector

## Lesson 4: Building a Solar Water Heater Collector

This lesson provides students with step-by-step instructions for how to build a solar water heater prototype. It includes an option to build a more permanent water heater. There are several different ways to build a solar water heater, but we will cover the key features in this lesson.

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### KEY WORDS

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**Riser Tubes:** tubes that contain the water being heated

**Thermal Insulation:** material which reduces heat transfer to the environment

**Collector Frame:** a box that holds the solar water heater components and reduces heat transfer to the surrounding environment

**Glazing:** a transparent cover that allows solar radiation in and keeps thermal

**Absorber Plate:** a material which helps transfer heat absorbed by the material to the riser tubes

**Miter Saw:** used to make accurate cuts in wood at one angle

**Router:** a tool used to hollow out space in a piece of wood, used to make the dado in the frame

**Spade Drill Bit:** a drill bit that is used to drill holes in wood

**Dado:** a notch to help hold something in place

## PREPARATION

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- Prior to the lesson, review all background material and purchase supplies. The materials required are listed in the activity explanation and sources for purchasing those materials can be found at the beginning of the unit. Students can use recycled cardboard boxes to use for the exterior of their collector. They may choose to use recycled materials for all components of their water heater prototype.
- Print the following handouts:
  - Handout 4.1 Building A Solar Water Heater Collector: 1 per student (for Build Option 1A)
  - Handout 4.2 Measuring Solar Water Heater Collector Efficiency: 1 per student
- Recommended Daily Lesson Breakdown:
- Day 1: Building a Solar Water Heater Collector
  - Discussion: Insulative and Conductive Materials
  - Activity: Building a Solar Water Heater Collector
  - Discussion: Efficiency of Solar Water Heaters
- OPTIONAL Day 2: Designing a Solar Water Heater Collector
  - Activity: Designing a Solar Water Heater
  - Discussion: Advantages and Disadvantages of building materials
  - Assignment: Collect materials for building the prototype.
- Day 3: Measuring a Solar Water Heater Collector Efficiency
  - Activity: Comparing the Efficiency of the Solar Water Heaters
  - Discussion:

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## DISCUSSION: INSULATIVE AND CONDUCTIVE MATERIALS

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- As discussed in Lesson 3 there are multiple types of home water heaters. After exploring the different options and identifying the advantage of solar water heating, today we will build our own solar water heater collectors.
- Recall that to build solar collectors, we'll need materials with high insulation values and materials with high solar radiation absorption factors and conduction rates.
  - What materials are good insulators? What materials are practical and affordable that could be used to insulate the collector?

- *Materials with high insulation values include fiberglass, wool, and glass. The cardboard will insulate the box, but an additional layer of wool or a towel could be used to increase the efficiency of the collector.*
- What materials are good conductors with high solar absorption factors? What materials are practical and affordable that could be used on the inside of the solar collector to absorb the maximum amount of heat?
  - *Most metals make good conductors. Generally darker surfaces are better at absorbing solar radiation. Check out this website for a list of materials and their solar radiation absorption factors: [http://www.engineeringtoolbox.com/solar-radiation-absorbed-materials-d\\_1568.html](http://www.engineeringtoolbox.com/solar-radiation-absorbed-materials-d_1568.html).*
  - *For this solar collector, foil can be used as a conductor. The entire system both foil and pipes could be painted black to increase the solar radiation absorbed by the system.*

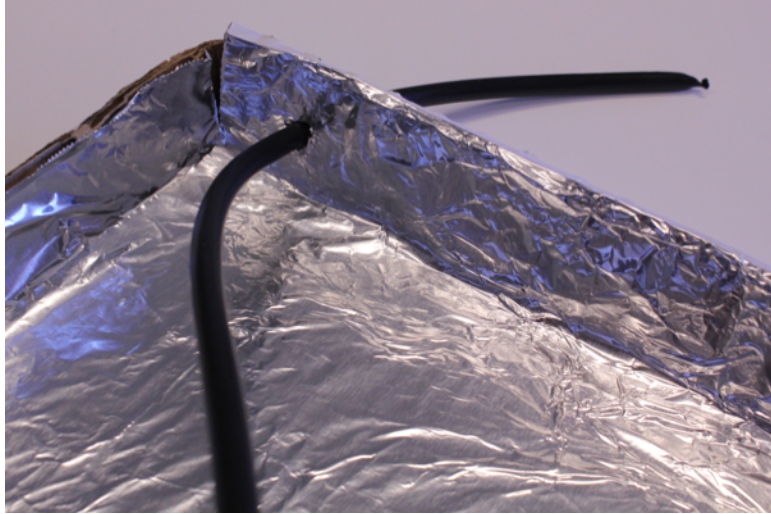
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## **ACTIVITY 1: BUILDING A SOLAR WATER HEATER**

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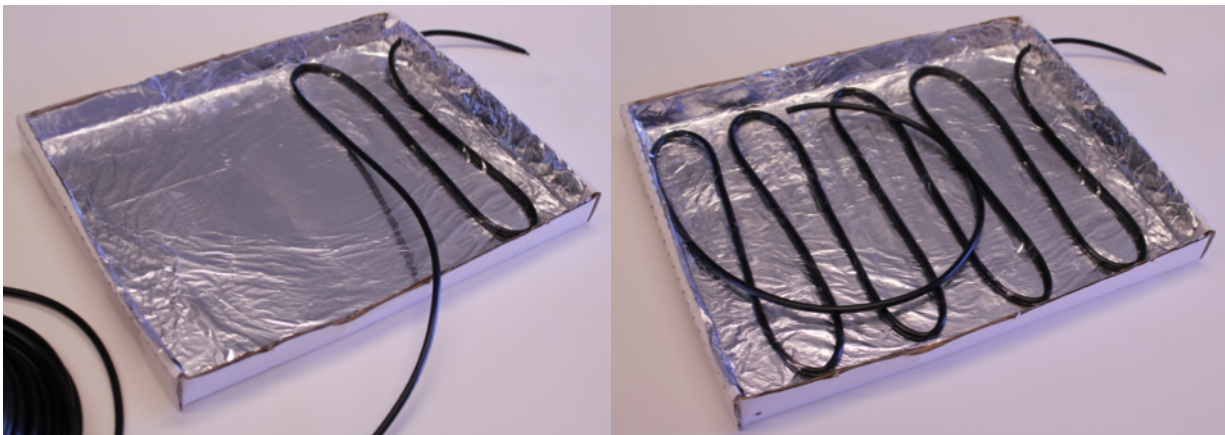
- This project works best with a small groups or pairs of students so they can work together to hold the tubing securely while they tape it. This project can allow for student innovation in the design of their water heater depending on which build option you choose.
- There are different options for you to complete this project with your students. In all options, students will design and construct a water heater and test its efficiency. If you do not have sufficient time or resources for constructing the prototype, you should skip the activities listed and instead have students create a scaled drawing with the different components and resources labeled.
- Option 1: Guided Build of a Solar Water Heater Collector
  - Option 1A: Box Top Solar Water Heater Collector
    - Use the detailed instructions for Option 1A: Box Lid Solar Water Heater Collector included in this activity description and the Building a Solar Water Heater Collector Handout to guide students through constructing their own solar water heater.
    - Note: The directions in the handout do not list materials. This will allow students to determine what they think the best options for insulation materials and solar radiation absorptions materials are. Before Activity 1 they should collect materials from home or class.
    - The directions in Activity 1: Building a Solar Water Heater below do include a materials list and pictures of those materials used in the example water heater.

### Option 1B: Wooden Box Solar Water Heater Collector



**Image 3**

5. Tape the piping down with clear plastic tape in a weaving or coiling pattern. Remember, the water is flowing through the system mostly via gravity. You may need to use a baster to pump the water through the pipe depending on the type of pipe you use. Try to make the curves so water is always following down through the system. Note: In order to ensure a smooth path for the water, do not kink the pipes. This will prevent an easy flow of water through your system.



**Image 4**

**Image 5**

6. Once you've reached the opposite end of the box, cut another hole at the base to feed the pipe back out of the box.



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## OPTION 1B: CONSTRUCTING A WOOD SOLAR WATER HEATING COLLECTOR

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- As an alternative to the Activity 1A in which students build a small prototype solar water heater using a cardboard box and drip irrigation piping, the next two sections describe how to construct a solar water heater using more durable, but expensive materials.
- The materials list below provides examples of materials that would increase the efficiency of the solar water heater. The materials are often more expensive and require a construction shop in order to build the water heater.

### Relative Cost for Materials - Less Expensive (\$) to More Expensive (\$\$\$)

#### Riser Tube Materials

- **Cross-linked Polyethylene or PEX (\$\$)** – PEX tubing is traditionally used in buildings for water piping
- **Polyethylene or Drip Irrigation (\$)** – Drip irrigation tubing is traditionally used for watering plants garden systems
- **Polyvinyl Chloride or PVC Tubing (\$)** – a clear tubing that is traditionally used for aquariums
- **Chlorinated Polyvinyl Chloride or CPVC Tubing (\$)** – a white-colored tubing used in plumbing applications
- **Copper (\$\$\$)** – metal tubing which transfers heat well, but is expensive

#### Thermal Insulation Materials (From <http://energy.gov/energysaver/articles/types-insulation>)

- **Foam Board (Panel) Insulation (\$\$)** – rigid or soft foam which comes in a slim boards
- **Blanket Insulation (\$\$)** – can be made from plastic, fiberglass or wool and other natural fibers
- **Reflective Insulation (\$)** – a reflective material that covers cardboard, bubble wrap, plastic or other insulating materials

#### Collector Frame Materials

- **Wood Boards (\$)** (Plywood, Pine, Etc.) – wood is easy to use and cheap given the right tools to work with it
- **Aluminum Metal Sheets (\$\$)** – given the proper tools, aluminum sheets can be used to form a collector frame and is a better conductor of heat than wood

#### Glazing Materials

- **Glass (\$\$\$)** – glass can be salvaged from old windows and doors for as glazing
- **Plexiglass (\$\$)** – a clear plastic material which is relatively cheap and wont shatter like glass
- **Fiberglass (\$\$\$)**

#### Absorber Plate Materials

- **Aluminum Sheeting (\$\$)** – using aluminum sheeting is a good way to transfer absorbed heat to the riser tubes

Note: This materials list is for two solar water heaters.

### List of Tools Used

- Table Saw
- Miter Saw
- Router
- Drill with Phillips Head Drill Bit
- Spade 3/4" Spade Drill Bit
- Hammer



### Collector Frame Materials

- Two .45' (H) X 23.25" (W) X 22.25" (L) Plywood Boards
- Four 1' (H) X 4' (W) X 23.25" (L) White Pine Wood Boards
- Four 1' (H) X 4' (W) X 20.25" (L) White Pine Wood Boards
- Twelve 1" Wood Screws

### Insulation Materials

- One 23.25" (W) X 22.25" Black foam insulation sheet
- One 23.25" (W) X 22.25" (L) Reflective bubble wrap insulation

### Glazing Materials

- Two 21.75" (W) X 20.75" (L) Plexiglass sheets

### Riser Tube Materials

- 100' Poly Drip Tubing
- Background: Work with what you have to make your example solar water heater. For example: You may have a limited of amount Plexiglas glazing. Therefore, you will want to cut the wood for your collector frame to maximize the amount solar radiation using the Plexiglas glazing.