Solar Energy

Lesson Plans

Photo: Dickinson College, PA
www.dickinson.edu

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www.efmr.org

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Background Information

Introduction

The sun is an inexhaustible source of energy. Solar energy is radiant energy from the sun caused by nuclear fusion in the sun's core. The sun's radiant energy reaches the earth in rays of sunlight. Solar energy in the form of heat and light sustains life on earth. Solar energy can also be collected, stored and put to work by converting it to pollution-free thermal (heat) energy and electricity. Less than 1% of the world's total electricity production comes from solar power. Current and future technologies to harvest the sun's energy could substantially increase this percentage. Interest and development of solar technology fluctuates as it competes with the varying costs of fossil fuels.

Solar Energy Basics

The sun's rays can only do work during daylight hours and lack of sunlight during cloudy weather also limits solar energy use. When conditions are right, the basic method of putting the sun's rays to work is in passive heating. Here, no mechanical devices are used and heat energy moves by convection in heating homes or pools of water. Building constructions such as large windows facing the sun contribute to passive solar power heating.

The sun's heat energy can actively be converted to generate water and space heating. Flat collection plates are placed on homes and buildings to face the sun's rays (directed south in the northern hemisphere). The collection plates have a transparent covering with dark metal plates beneath which absorbs heat. The heat is transferred to water in pipes below the plates. The heated water flows to storage tanks and is transported to needed areas. Heated air can also be collected and absorbed in materials such as tiles, concrete or rock beds. Circulating pumps and fans transport the air. Heat energy collection and use is limited with flat solar collection plates. Heating systems using conventional heating fuels are typically used in conjunction with solar heating.

Solar energy can also be used to produce electricity through thermal conversion or direct conversion using photovoltaics.

Concentrating Solar Power for Electricity

Advanced technologies have made solar energy more competitive with conventional energy fuels for generating electricity. Concentrating solar power technology produces much higher temperatures which can be used for heating and producing electricity. Large curved mirrors are used to reflect sunlight from a large area and focus it on a much smaller blackened area. Solar power plants use computer-controlled sun-tracking reflectors which move to face the sun's rays. The sun's thermal energy is reflected and focused on a large water boiler often on

a tower. The fluid boils to produce steam which drives a turbine to generate electricity. Large solar power plants use new concentrating solar power technologies and are developing new polymer materials to replace the more expensive glass mirrors. Concentrating solar power is the most cost effective method to harness the sun's energy for generating electricity.

Photovoltaic Energy

Solar cells called Photovoltaic (PV) cells convert sunlight directly into electricity. Semiconductor materials absorb sunlight energy and create an unbalanced flow of electrons from one side of the solar cell to the other. The sides are connected with a metal material which allows the electrons to travel. The flow of electrons produces electricity. Solar cells are often used in small devises such as calculators. Numerous photovoltaic cells can be interconnected to produce more power.

Currently, the large-scale use of photovoltaic cells is not economically competitive in the market of electricity generation. The U.S. Department of Energy, along with non-government agencies and universities are working together on the Solar America Initiative (SAI). Their goal is to aggressively develop PV technologies making electricity from PV cells economically competitive with conventional electricity by the year 2015.

Environmental Impacts

The quest for clean, sustainable sources of energy is becoming more popular with the concerns over global warming. Scientific communities have determined that carbon dioxide emissions, from the use of fossil fuels, contribute to the greenhouse effect. Solar energy is unlimited and harnessing it for heat and electricity produces no air or water pollution. The development of solar energy technologies can only help our environment by decreasing CO_2 emissions and reducing drain-off pollution from fossil fuel power plants.

Solar Energy
Elementary Lesson Plans

National Science Education Content Standards: B,F
PA Academic Standards: 4.2, 4.8
Subject Areas: Science, Language Arts, Social Studies

Unit Objectives

Students will:

1. Define solar energy as clean, renewable energy from the sun.
2. Observe and identify solar energy doing work.
3. Experiment and conclude that solar energy can be collected for use.

Activity 1: The Sun as our Primary Energy Resource

Objective

Students will describe and illustrate the sun as our primary source of energy.

Materials

yellow construction paper cut in a large circle (sun model), vegetable oil, clear cup, internet access or resource books

Procedure

Discuss and define "energy" as the ability to do work.
Review with class that "work" is done when something moves or changes. Potential energy is stored energy or the energy an object contains. Kinetic energy is energy in motion or doing work. There are different forms of energy which include (but are not limited to) heat, mechanical and electrical energy. Fuels or energy resources are needed to produce energy.

Introduce the fuels or resources needed to produce energy. Relate how our bodies use food as fuel to help us function or give us energy. As a class, list types of energy resources or fuels used to produce energy: coal, petroleum, natural gas, wind, water, solar, wood, etc. Introduce the sun as our primary energy source. Discuss the sun's heat and light energy as being essential for life on earth. (Plants need sunlight to make food through the process of photosynthesis, and animals eat plants. Heat energy is needed by plants and animals for survival.)

Display sun model and a clear cup of oil.
Ask students which energy resource can be used up. Discuss the term, "renewable." Have volunteers explain the difference between renewable and nonrenewable resources.

In addition to supplying plants and animals with heat and light, list simple examples of solar heat energy doing work such as wet clothes drying outside, pool water being heated, puddles drying up etc.

Evaluation

Have students draw pictures or create mobiles that illustrate the sun's energy doing work. They should draw a sun in the center with examples drawn around it.

Activity 2: Colors that Absorb Heat

Objectives

Students will experiment and conclude that dark colors absorb more heat energy than light colors.

Students will determine that solar collectors have black surfaces to absorb more heat energy.

Materials

thermometers, cone-shaped spot lamps, small cans (i.e. tomato juice cans) wrapped with black construction paper and same number of cans wrapped with white paper and secured with rubber bands), black and white paper lids with slits cut in middle, assorted colors of construction paper, measuring cups, water containers, data sheets, picture of solar collector plates

Procedure A: Early Elementary

Review the sun as our primary source of energy for supplying us with heat and light energy. Have students give examples of when they have experienced the sun heating different objects.

Place white and black sheets of construction paper on table (or outside on a sunny day), and have students place a spot lamp equal distances from both. Students place ice cubes of equal size on each colored paper and turn on lamp. Have students observe which melts faster and explain results. They should complete three trials with the white and black papers. If time permits, allow students to experiment with other colors. Discuss results.

Evaluation

Students draw illustrations to demonstrate how dark colors absorb heat faster and cause the ice cubes to melt more quickly.

Procedure B: Upper Elementary

Discuss how heat can be measured in relative estimated terms and precise degrees. Review how a thermometer measures temperature in both Celsius and Fahrenheit scales. Distribute thermometers and allow students time to determine room temperatures and review measurements.

Divide class into groups of three or four. Distribute a set of white and black cans, measuring cup, containers of water and cone or lab lamps to each group. Have students pour equal amounts of water into cans and place matching colored lids on top. Place thermometers through each lid and into center of water.

Have them predict which color will warm the fastest when a heat energy source is directed at both the black and white cans. Students place lamps equal distances from cans making sure to provide the same exposure to both. Have students record temperatures every five minutes for fifteen minutes. Discuss results. (The black can should heat much faster.)

Introduce solar collection plates (See Background Information.) and discuss the importance of using black material to absorb heat energy.

Evaluation

Students complete activity and data charts with conclusions stating that dark materials absorb more heat energy than lighter colored materials.

Enrichment

Take students outside on a hot sunny day. Place thermometers on different colored objects. (If viable and safe, place on the hoods of dark colored cars and light colored cars.) Record temperatures to conclude that dark colors absorb more heat energy.

Activity 3: Solar Cooking (on a hot, sunny day)

Objectives

Students will demonstrate how the sun's heat or thermal energy can be used to do work (cook).

Materials

cast iron frying pan, aluminum pan, oil, egg

Procedure

Review previous experiment and reinforce the conclusion that black or dark colors absorb heat energy better than light colors. Facilitate a discussion on what would be the best colored material to absorb the sun's heat energy.

Take students outside on a hot, sunny day. Place pans on the ground in direct sunlight and coat the bottom of each pan with oil. Wait several minutes and have two students each break an egg and put one in each pan at the same time. Students observe eggs (cooking) for several minutes. Discuss results.

Evaluation

Students explain and draw illustrations of the eggs being cooked by solar heating.

Activity 4: Researching Solar Collectors (upper elementary)

Objective

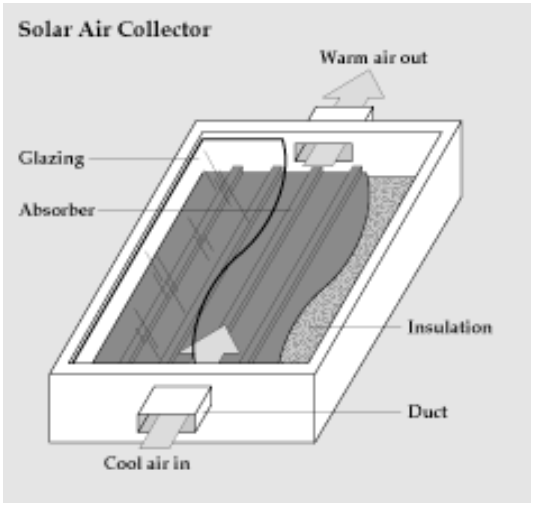
Students will research and explain the basic function of solar collectors.

Materials

pictures or samples of solar collectors, internet access (optional) and/or encyclopedias

Procedure

Show pictures and examples of solar collecting devises and discuss how each is useful. Display diagram of a basic solar air collector and have students identify the dark-colored absorber and glazing or cover.



U.S. Department of Energy
www1eere.energy.gov/solar/sh_basics_collectors.html

Review with class that solar energy can be collected and used to supply heated air and water for buildings.

Assign individual or group research on solar power topics. Research ideas can vary depending on grade level. Informative websites include:

www.need.org	National Energy Education Development Project (NEED)
www.energy.gov	U.S. Department of Energy
www.nrel.gov	National Renewable Energy Laboratory
www.dep.state.pa.us	PA Department of Environmental Protection

Evaluation

Describe and diagram how solar collection plates are used to capture the sun's energy and provide heated air and water for buildings.

Enrichment

Take the class on a tour of a "Green Building" or one that has easily visible solar collectors.

Solar Energy
Middle School Lesson Plans

National Science Education Content standards: B, E, F
PA Academic Standards: 4.2, 4.8
Subject Areas: Science, Social Studies, Language Arts, History

Unit Objectives
Students will:
1. Evaluate solar energy as renewable, clean energy.
2. Demonstrate and explain how a solar collector absorbs and transfers the sun's heat energy.
3. Create a solar collector.
4. Determine that solar energy can be converted into electricity.
5. Research and identify developments in the history of solar power.

Activity 1: Solar Energy Basics

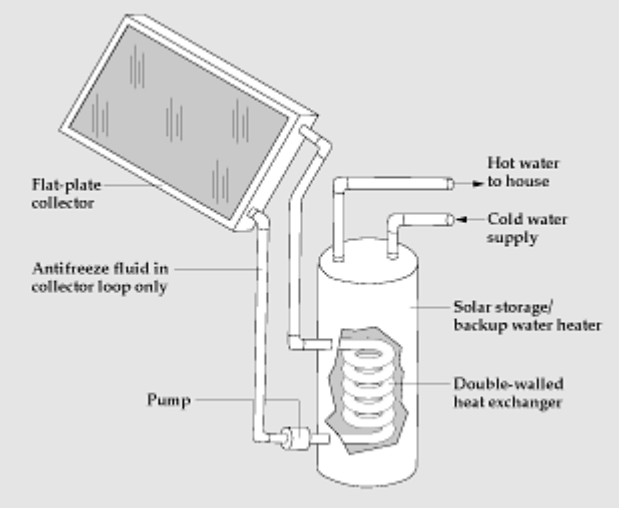
Objectives
Students will identify solar energy as renewable, clean energy.
Students will identify flat panel solar collectors and explain how they absorb and transfer the sun's heat energy.

Materials
"Background Information", diagram of flat panel solar collector and solar hot water heater, encyclopedias, internet access

Procedure
Review the sun as our primary source of energy (with energy defined as the ability to do work) and Elementary Lesson #1, if needed. Direct students to write definitions of "renewable energy" and "nonrenewable energy" and give two examples of each. Discuss and review.

Introduce or review the process of nuclear fusion. Explain briefly as the combining of the nuclei of atoms to release energy. (Teachers may want to discuss the "Law of Conservation of Energy" which states that energy cannot be created or destroyed; it can only be transformed into another form of energy.) Have students give examples of how the sun's radiant heat energy can be captured and put to work.

Display diagrams of solar collector hot water heater. Have students locate the flat collection plate. They may refer to the diagram to describe how solar energy is collected and used to heat water.



"An indirect solar hot water system."
U.S. Department of Energy
www.eere.energy.gov/de/solar_hotwater.html

Evaluation

Students research and report on flat-plate solar collectors and their uses.

Activity 2: Comparing Solar Collectors

Objective

Students will compare and create models of nonconcentrating and concentrating solar collectors.

Materials

diagrams of solar collectors, aluminum foil, thermometers, bowls, black construction paper and other black-colored materials, reflectors used for tanning (optional), computer, internet access and website:
www.eere.energy.gov U.S. Department of Energy
Energy Efficiency and Renewable Energy

Procedure

Review information: "Solar Energy Basics" and "Concentrating Solar Power for Electricity" (pg. 4-5). Distribute diagrams (or view on internet) of flat-plate solar collectors and concentrating solar collectors. Have students compare their construction and ask which may be more efficient for capturing the sun's energy. (Both have large collecting areas. The concentrating solar collectors have curved mirrors that reflect the sun's rays from a large area onto a much smaller black-colored absorbing area.)

Set materials (aluminum foil, bowl, and black heavy paper) on table and ask several volunteers to create a simple model of a flat-plate collector and a

concentrating collector using these materials. (The foil can be pressed into the bowl and removed to create a mold of a reflector. The reflectors should focus on black paper in the center.)

Have students work in pairs to research and compare flat-plate collectors and concentrating collectors using the internet. The basic construction and uses can be written in a report. They may also get ideas for constructing their own models of each type of collector. Aluminum foil or mirrors can be slanted and arranged in a round area with an opening at the bottom. (The reflectors used for tanning are good examples.) Allow two weeks for students to complete their reports and construction of solar collector models.

Take students outside on a sunny day and have them set up their solar collectors. Have students move thermometers to different areas of the collection surfaces to determine the hottest spots. Students place thermometers in hottest spots (focus points on concentrating collectors) of each and make a recording every three minutes for a fifteen minute period. Discuss results.

Evaluation

Students complete their models of solar collectors and demonstrate to the class. Written descriptions of their collector and an evaluation of their findings may be reported.

Activity 3: Solar-powered Electricity

Objective

Students will research and explain how solar energy can be captured and converted into electricity using two methods: thermal conversion and solar cells (photovoltaic cells or PV cells).

Materials

available solar-powered devices such as outdoor solar lights, solar-powered calculator, dictionary, internet access, small radiometer (optional), conclusions from lesson # 2

Procedure

Teacher may need to review "Background Information." Refer to previous lesson, and ask which type of collector absorbs more of the sun's energy (concentrating collectors). Introduce solar energy electricity production.

Discuss the solar thermal process of generating electricity in solar power plants. See "Concentrating Solar Power for Electricity" (pg. 4). Explain the process in basic or advanced terms. (Concentrating solar collectors absorb the sun's heat energy and boil fluids to produce steam. The steam moves the blades on a turbine which causes it to spin. The spinning turbine rotates a shaft connected to a generator to produce electricity.)

Show students solar light and have them locate the solar collector. Ask what kind of energy sunlight is converted to. (Electrical)

Introduce solar cells as being called photovoltaic cells. Have a student read the definition of "photovoltaic" from a dictionary. See "Photovoltaic Energy" (pg. 5). Review the concept that solar or PV cells change sunlight directly into electricity. Note that PVs are generally used in small devices and satellites.

Have students research one or both of the ways solar energy is used for electricity generation.

Evaluation

Students complete research and illustrate examples of solar thermal electricity and photovoltaic energy.

Enrichment

Have students bring in devices that have solar cells and set up a display table.

Tour a solar power plant or visit a building that produces solar thermal electricity.

Activity 4: Solar Energy Timeline

Objective

Students will research the history of solar power and create a timeline.

Materials

encyclopedias, internet access and websites:
www.eia.gov./kids/history/timelines/solar.html
(Energy Information Administration)
www1.eere.energy.gov/solar/solar_timeline.html
(U.S. Department of Energy: Energy Efficiency and Renewable Energy)

Procedure

Divide students into groups to research specific time periods in the history of solar power:

BC – early AD	passive solar heating, magnifying lenses and mirrors used to focus sunlight for heat, making fires and cooking
1600-1700s	solar heat experimentations, early solar collectors (1767)
1800s	invention of solar-powered steam engines, solar water heaters
1839	photovoltaic effect discovered
1900-1950	developments of solar boiler and photoelectric effect experiments
1954	photovoltaics or solar cells invented
late 1950s	solar cells used on space satellites
1960-70s	widespread use of PV cells
1980s	first solar-powered aircraft and car built, solar-thermal electricity become feasible
1990-2000	PV cell technologies develop with solar-powered buildings, aircraft and automobiles
2001-2008	Solar cells become more efficient. Increased interest promotes technological developments.

Have student groups present their research and list on class timeline with simple illustrations.

Evaluation

Students complete research, present their findings to the class and list on a classroom timeline.

Enrichment

Have students collect current events relating to solar power and post in classroom. Review as time allows.

Solar Energy
High School and Advanced
Lesson Plans

National science Education Content Standards: B**,** D, E, F
PA Academic Standards: 3.8 4.2, 4.8
Subject Areas: Science, Social studies, Language Arts

Unit Objectives
Students will:
1. Explain the "Conservation of Energy" and relate to solar energy.
2. Research and report on current and projected solar energy technologies
3. Determine solar power consumption and production.
4. Design and create a model of a working concentrating solar collector.
5. Research and identify the advantages and disadvantages of solar energy systems.

Activity 1: Solar Energy and Advanced Technologies

Objective
Students will recognize and explain the "Conservation of Energy."
Students will research and report on advanced developments in solar energy technologies.

Materials
outdoor solar light, Internet access:
www1.eere.energy.gov/solar/about.html
(U.S. Department of Energy: Energy Efficiency and Renewable Energy)
www.ises.org The International Solar Energy Society
www.eia.doe.gov Pennsylvania Department of Environmental Protection

Procedure
Review or Introduce:
The sun's radiant energy is a result of nuclear fusion within the sun's core. The earth receives solar radiation in rays of sunlight. Sunlight is a flux of photons, or particles of solar energy. Review the "Law of Conservation of Energy" which states that energy cannot be created or destroyed; it can only be transformed into another form of energy. (The total amount of energy remains constant.) Solar energy can be transferred and converted to thermal energy and electricity.

Teacher may need to review "Background Information." Review the fact that solar energy can also be used to produce electricity in two ways: the thermal process and with solar cells (photovoltaic cells). Through the thermal electricity generating process, solar collectors heat water which turns to steam and causes a machine (which consists of a spinning turbine driving a generator) to produce electricity. Solar cells (photovoltaic cells) can change sunlight directly into

electricity. These cells are used in small items such as calculators and also in space satellites.

Display solar-powered lights and ask students to explain how they work. Introduce the solar technology of converting the sun's energy into electrical energy.

Have students research advanced solar electric technologies (They may research "Solar America Initiative") using several websites. State and Federal Departments of Energy regularly update information.

Evaluation

Students research, illustrate and report on advanced solar energy technologies, primarily electricity generating.

Enrichment

Tour a solar power plant or building which has solar-powered electricity.

Activity 2: Creating a Solar-Powered Machine or Model

Objective

Students will design and create a model or working solar-powered devise.

Materials

internet access

Students supply materials with teacher's assistance.

Procedure

Review and discuss research on solar energy technologies. Assign a several week-long project of designing and creating a working solar-powered apparatus or model. Students may work in groups or independently to develop and present their creations to class. Choices for projects may include the following:

-concentrated solar collector for cooking

-small model of a solar water heater with heat transferred from collector to water container to an output.

-a model demonstrating solar thermal electricity (with collector and rotating object representing a turbine)

-a model or working PV cell devise (small PV cells can be obtained through science catalogs) see: www.infinitepower.org (Texas State Energy Conservation Office)

Evaluation

Students complete solar-powered projects and present to class.

Enrichment

Invite a solar energy specialist or representative from the State Department of Energy for a class presentation.

Activity 3: Solar Electricity: Potential and Generation

Objective

Students will research, report and evaluate solar electric power generation in their state, nationally and world-wide.

Materials

current world almanac, Internet access:

www.nrel.gov Renewable Resource Data Center: National Renewable Energy Laboratory (NREL)
(search Solar Maps: U.S. Solar Atlas)

www.energy.gov U.S. Department of Energy

www.eia.doe.gov Energy Information Administration

www.dep.state.pa.us Pennsylvania Department of Environmental Protection

Procedure

Discuss solar energy as a resource and have students list locations they believe would be conducive to solar energy electricity generation. Distribute paper copies of solar maps or view on internet. Review locations in their state and the nation.

Visit additional websites for world-wide solar-powered electricity. Have students suggest other locations that seem viable for solar power systems.

Annual average daily solar radiation per month, using a flat-plate collector facing south at a fixed tilt equal to the latitude of the site. Capturing the maximum amount of solar radiation throughout the year can be achieved using a tilt angle approximately equal to the site's latitude.

www.nationalatlas.gov

Have students do further research to compare electric power generation of solar power plants. Megawatts of power generated should be researched in their

state, nationally and world-wide. They should report the statistics by way of a chart or graph.

Evaluation

Students complete data collecting and illustrate on a chart with notations.

Enrichment

Students may investigate the reasons behind a lack of solar energy systems in locations where it seems viable that they should be.

Activity 4: The Pros and Cons of Solar Energy

Objective

Students will research and evaluate the advantages and disadvantages of solar energy systems.

Materials

internet access, collective information

Procedure

Facilitate a discussion on the advantages and disadvantages of large-scale solar energy systems. Discuss variables for marketability.
Include environmental issues, costs, sustainability and maintenance.
Advantages:

*Solar energy is renewable (unlimited).

*Solar power production is nonpolluting and quiet which makes it environmentally friendly.

*Aggressive construction of solar power plants could reduce dependence on nonrenewable energy resources such as petroleum.

*Maintenance costs are minimal.

Disadvantages:

*Start-up costs are substantial.

*Solar power production is dependent on the sun shinning. Night hours and cloudy conditions cease production.

*Storage batteries and back-up systems are generally needed.

*Solar collectors require large areas for construction.

Have students research and collect additional notes on the pros and cons of solar energy. Allow students to express which points are of major concerns to them individually. Assign a descriptive chart listing the advantages and disadvantages.

Evaluation

Students complete research listing the advantages and disadvantages of solar energy production and also express the points most significant to them.

Enrichment

Encourage students to stay informed with current bills and legislation related to solar energy programs. Motivated students may contact state and federal agencies and officials to request additional information and voice their opinions.

Academic Standards

PA Academic Standards for Science and Technology

Physical Science, Chemistry and Physics	3.4
Science, Technology and Human Endeavors	3.8

PA Academic Standards for Environment and Ecology

Renewable and Nonrenewable Resources	4.2
Humans and the Environment	4.8

www.pde.state.pa.us

National Science Education Content Standards

Physical Science	B
Earth and Space Science	D
Science and Technology	E
Science in Personal and Social Perspectives	F

www.nsta.org/publications/nses.aspx

Website Resources

Dickinson College, Carlisle, PA
(front cover photo)
www.dickinson.edu

Energy Information Administration
(Official Statistics from U.S. Government)
www.eia.doe.gov

The International Solar Energy Society
(Current Technologies World-wide)
www.ises.org

National Energy Education Development Project (NEED)
(Solar Energy Infobooks and Activities)
www.need.org

National Renewable Energy Laboratory (NREL)
National Renewable Resource Data Center
(Solar Resource Maps, Statistics and Information)
www.nrel.gov

National Science Teachers Association
(National Science Education Content Standard
www.nsta.org/publications/nses.aspx

Pennsylvania Department of Education
(PA Academic Standards)
www.pde.state.pa.us

Pennsylvania Department of Environmental Protection
(Current Projects and Legislation Related to Solar Energy)
www.dep.state.pa.us

Texas State Energy Conservation Office
(Renewable Energy Information and Lesson Plans)
www.infinitepower.org

U.S. Department of Energy
Energy Efficiency and Renewable Energy
www.eere.energy.gov

Union of Concerned Scientists
Citizens and Scientists for Environmental Solutions
www.ucsusa.org

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