the CEED

THE CENTER FOR ENERGY EFFICIENT DESIGN

Title: Forms of Energy			
Grade Level	5	**Subject**	Investigating Solar Cells and Forms of Energy

Objective(s):

In this lesson, students use a selection of solar panels, lamps, motors, and an AA battery to get as many motors or lights to operate as they can in an allotted time period. For each successful arrangement, they draw a diagram of their setup, label the energy source and the forms of energy used, and make predictions about how long each power source might be able to operate a device.

SOL Addressed:

4.3-The students will investigate and understand the characteristics of electricity. Students will understand that electrical energy can be transformed into light and motion, and produce heat.

5.1-The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations.

Common Core Standards:

4-PS3-2. Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.

4-PS3-4. Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.

4-ESS3-1. Obtain and combine information to describe that energy and fuels are derived from natural resources and their uses affect the environment.

3-5-ETS1-1. Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

3-5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

3-5-ETS1-3. Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

Materials Needed Per Class of 30 **and** **Prior Knowledge**	**Per work group** One or two (different if possible) small DC motors having an operating range of roughly 1–4 volts One or two (different if possible) light-emitting diodes (LEDs) One or two (different if possible) small incandescent flashlight bulbs Two 1V, 400 mA mini–solar panels with alligator clip leads* Sunlight, a gooseneck lamp with 100-watt incandescent bulb, or both One AA battery in holder with alligator clip leads **Safety:** Warn students not to touch lighted incandescent bulbs, since they become hot enough to cause a burn. Do not let the alligator clips on the two wires connected to the battery touch, since the battery will quickly become "dead" (also, the battery might become hot enough to cause a burn). **Prior Knowledge:** **Photovoltaic Cells:** When a solar cell is exposed to typical light sources, negatively charged electrons almost instantly move to the top of the cell, leaving behind a crystal lattice of atoms having more positively charged protons than negatively charged electrons on the bottom of the cell. This movement rapidly reaches an internal state of equilibrium where the solar cell exhibits a voltage difference of about 0.5 volts between the top and the bottom of the cell. When metal contacts are placed on the top and the bottom of a photovoltaic cell (solar cell) and each cell is connected to an electric circuit, electrons are drawn off the top of the cell, producing a current that can be used externally. Electrons from the top of the cell move through the electric circuit, replacing the missing electrons in the bottom of the cell. This movement continues as long as the cell is exposed to light having photons of sufficient energy to excite the photovoltaic crystal's electrons. **Power Versus Energy:** Power is the rate at which work is done. Energy is the capacity of a physical system to do work. In this lesson, power is proportional to how fast a motor spins or how bright a bulb glows. Energy available to do work depends on the circuit present. Circuits powered by batteries have energy to do work as long as the batteries are "charged" rather than "dead." The length of time that such a circuit will do work depends on the amount of energy stored in the battery. Circuits powered by solar cells have energy to do work as long as light is present. **Light-Emitting Diodes (LEDs):** A light-emitting diode produces light when current passes through it. Unlike an incandescent bulb, current can pass through an LED in only one direction. LEDs are now readily available in flashlights and in strings of Christmas tree lights. LEDs typically can be purchased in electric supply stores.

<table>
<tr><td rowspan="1">Ways to differentiate this lesson plan</td><td colspan="2">
EXTENSION for Higher Level Learner
Check to see if any teams noticed that LEDs work only when the red and black wires are connected according to the proper polarity (red to the positive terminal, black to the negative terminal), but that the motors and incandescent lamps work when the red and black wires are connected to either terminal. If so, have those students research the literature to come up with explanations for the phenomena.

MODIFICATIONS for Student Support
Provide students with a sample diagram. Ask these students additional questions to guide their thinking as they perform the investigation and/or work with these students in a small group.
</td></tr>
<tr><td>Introduction/ Anticipatory Set</td><td>
Anticipatory Set:

Introduce the concept that there are different forms of energy, such as light, mechanical, electrical, chemical, and heat energy.

Questions to ask students:
What is energy? Energy is the ability to do work.

Describe the different forms of energy and give examples of each.
What Energy Does—energy is recognized in many ways.
Light is energy, and the transformation of energy produces light—the movement of energy in transverse waves or rays is called radiant energy.
Heat is energy, and the transformation of energy produces heat—the movement of atoms and molecules within substances is called thermal energy.
Motion is energy, and the transformation of energy can produce motion—energy of motion is called kinetic energy.
Growth requires energy, and the transformation of energy within living things can produce growth—the energy needed for plants to grow comes from radiant energy and the energy needed for everything else to grow is stored in the bonds of substances and is called chemical energy.
Electricity is energy, and the transformation of energy can produce electricity—when electrons move through a substance it is called electricity.
</td><td>
Introduction:

Go the CEED dashboard and click on wind energy. Go to the “extras” tab and click on “how they work”. Discuss energy terms with students and have them discuss and answer questions with partners. Point out that the electric company measures how many kilowatt hours your home uses in a month and sends you a bill for that month.

Forms of Energy—energy is recognized in many forms, all of which are potential or kinetic.
Radiant Energy (Light, X-rays)
Thermal Energy (Heat)
Motion Energy (Wind)
Chemical Energy (Energy in Wood, Fossil Fuels)
Electrical Energy (Electricity, Lightning)
Stored Mechanical Energy (Springs)
</td></tr>
</table>

Guided Practice	1. State that solar cells are objects that convert light energy into electrical energy. Hold up a mini–solar electric panel and show students that it is made up of solar cells. 2. Tell students that the CEED building uses solar cells to produce electricity and conserve energy. Show students the video on the CEED building from the website. 3. First, students will read the "photovoltaics" section under "How It Works" with a partner. Next, have students explore the Data Dashboard with their partner. 4. The teacher will facilitate exploration by asking questions as students discuss ideas. Questions: What does photovoltaic mean? Light and Volts (electricity) What do PV cells (solar cells) do? Supply energy to items that are powered by batteries or electrical power What happens when sunlight strikes a solar cell? Electrons move which produces electrical current How fast does this happen? Instantly Look at the different types of solar collectors. Discuss their differences. Compare values for different types of solar collectors. Describe what you see. What factors lead to the differences in energy collected? Why would you ever have to change the angle of the panels? Seasons The tracking system is the only device that uses electricity from the grid-tied system.
Independent Practice	Form student teams of two or three. Provide each team with two solar cells, 1 AA battery in a holder, motor(s), a selection of light-emitting diodes (LEDs), a selection of small flashlight bulbs, and if direct sunlight is unavailable, a gooseneck lamp with a 100-watt incandescent bulb. Challenge students with the task of connecting together items they have been given in ways that will cause a lamp to shine or a motor to spin. For each successful arrangement, complete the following: 1. Assign the arrangement a test number. 2. Draw a diagram that shows how the items used are connected. On your diagram, label each item and the color of the wires. 3. On your diagram, identify where each of the following forms of energy is present. (Light, Mechanical, Electrical, Chemical, and Heat) 4. Where does the energy that powers the small lamp or motor come from? 5. How fast is the motor spinning, or how bright is the lamp operating? On a scale of one to five, circle the appropriate number. Lamp- 1 (dim), 2, 3, 4, or 5 (bright) Motor-1 (slow), 2, 3, 4, or 5 (fast) 6. How long do you predict the motor or lamp will remain on, if left as you have it connected? Back up your claim by explaining your prediction.

	Tell students the cost of a 1V, 400 mA solar cell ($5.00), and the cost of one AA battery. Help them, as needed, as they calculate the cost of running a motor with a battery versus a solar cell for one hour, one week, and one month.
Closure (Summary of Lesson)	All student groups will present one of their diagrams to the class, along with their answers to the questions/data and conclusions. They will also give one way they could improve their work. Review with students the different forms of energy that they encountered. Stress the particular form of energy at the source of power (light for photovoltaic-powered circuits and chemical for battery-powered circuits). Compare the concept of power with the concept of energy. Ask students to identify which test setups produced more power as evidenced by a faster turning motor or a brighter glowing bulb, and which setups had the longer lasting source of energy. Discuss the pros and cons of powering simple circuits using solar cells versus batteries (see the Background Information section).
CEED Building Application/ Sensor Data	Students are introduced to the CEED dashboard in the introduction of the lesson. They will become familiar with energy terms and things that produce one kilowatt hour. Students will also watch the CEED building video to learn about solar panels and read about photovoltaics. Finally, students will explore the data dashboard and ask/answer questions as the teacher facilitates discussion.
Assessment	Teacher will check student understanding- 1. Clearly drawn and labeled diagrams 2. Correct labeling of each form of energy that exists in the circuit depicted. 3. Correct identification of the source of energy (light from the Sun or a light bulb for photovoltaic-powered circuits and stored chemical energy for battery-powered circuits). 4. An appropriate identification of the power output provided by the circuit. 5. An explanation of the energy available to power the circuit.

INQUIRY LEARNING RESEARCH PROCESS GUIDELINES

CEED

Instructional Activities

The following table is just one guideline to use for developing your own inquiry materials. The seven steps in the Learning Research Process include not only how people learn but also how research is conducted. The heart of the design, the three-stage learning cycle of exploration, concept invention or formation, and application is embedded in the middle. In addition to these three stages, this design takes into account that learners need to be motivated to spend the time required for understanding complex subjects and that learners need to build this new knowledge onto prior knowledge. These are similar to the 5E and 7E learning models.

The Learning-Research Process

Steps in the Learning-Research Process	7E Equivalent	Component of the Activity
1. Identify a need to learn.	Engage	An issue that excites and interests is presented. An answer to the question *Why?* is given. Learning objectives and success criteria are defined.
2. Connect to prior understandings.	Elicit	A question or issue is raised, and student explanations or predictions are sought. Prerequisite material and understanding is identified.
3. Explore	Explore	A model or task is provided, and resource material is identified. Students explore the model or task in response to critical-thinking questions.
4. Concept invention, introduction, and formation	Explain	Critical-thinking questions lead to the identification of concepts, and understanding is developed.
5. Practice applying knowledge.		Skill exercises involved straightforward application of the knowledge.
6. Apply knowledge in new contexts.	Elaborate and Extend	Problems and extended problems require synthesis and transference of concepts.
7. Reflect on the process	Evaluate	Problem solutions and answers to questions are validated and integrated with concepts. Learning and performance are assess

Hanson, D. (2006). POGIL Instructor's Guide to Process-Oriented Guided-Inquiry Learning. Lisle, IL: Pacific Crest