Lesson Two

Lesson 2

PHOTOVOLTAIC SOLAR ENERGY

TEP BRIGHT STUDENTS: THE CONSERVATION GENERATION

Grade level appropriateness: Grades 6-8

Lesson Length: 1 full class period (~ 60 minutes)

Additional documents:

- Student Worksheet: Models, Systems, and PV Energy
- Student Worksheet: Models, Systems, and PV Energy - Answer Key
- Photovoltaic Cell and Circuit Picture 1
- Photovoltaic Cell and Circuit Picture 2
- Modeling Electron Flow in a PV Cell and Circuit
- The Parts of a PV Cell Picture 1
- The Parts of a PV Cell Picture 2

TEP
Tucson Electric Power

LESSON 2

Intro

Introduction/Overview

PHOTOVOLTAIC SOLAR ENERGY

After a short discussion about solar energy and solar applications that students have seen in their own lives, students arrange chairs in the classroom to represent a simple model of a PV cell and electric circuit. Students become part of the model, acting as electrons stimulated into movement by sunlight (a flashlight). The student-electrons move between chairs to illustrate the photovoltaic effect and how the flow of electrons from a PV cell through an electric circuit powers an electric load (simulated by a bell or buzzer). Discussion points include comparison of this model of a PV cell with actual PV cells, among other topics. A provided homework sheet provides a review and assessment of student understanding.

Core Concepts

Sunlight, also called solar radiation, is the most inexhaustible, renewable source of energy known to humankind. Use of solar energy may be passive or active. Passive solar energy involves using the sun's energy with little or no mechanical or electrical devices. Active solar energy uses electrical and/or mechanical equipment. Photovoltaic energy is a form of active solar energy. Photovoltaic energy is created when sunlight is converted on an atomic level directly into electrical energy. The photovoltaic effect occurs when light energy absorbed by a semiconductor energizes electrons, freeing them from their atoms so they can flow through the material to produce electricity.

PV technology can be used on almost any scale, from calculators and wrist watches to a single private home to large-scale commercial power plants. PV power has proven extremely dependable and PV equipment can operate reliably for long periods of time with no pollution, no fuel source needed, virtually no maintenance, and minimal operating costs.

Learning Objectives

After completing this lesson, students will be able to do the following:

- State that solar energy is the most inexhaustible source of energy
- Describe how the light energy of the sun is converted directly into electric energy in photovoltaic cells
- Define the photovoltaic effect as the effect of sunlight energy exciting electrons in certain materials, freeing them to flow and thus produce electricity
- Define model
- Compare and contrast the class model of a PV cell with a real PV cell

Advance Preparation

MATERIALS NEEDED

- Student Worksheet: Models, Systems, and PV Energy – photocopy one per student
- Overhead Images: A Photovoltaic Cell and Circuit 1 and 2
- Overhead Image: Modeling Electron Flow in a PV Cell and Circuit
- Overhead Images: The Parts of a PV Cell 1 and 2
- Chalk or white board
- Chalk or white-board markers
- Overhead projector and markers or Smart Board and markers
- Paper and pencils – one each per student
- Wide masking tape or similar (bright colors if possible)
- Manual (not electric) buzzer, bell, or similar object
- Chairs or desks – one per student
- Optional: samples of PV cells
- Optional: flashlight

GENERAL PREP

- Optional: Contact local or other solar equipment providers to see if they will contribute sample PV cells. (These need not be functional; the idea is to let students see and handle actual PV cells. Cells sold through science supply houses are typically sheathed in plastic to protect them during student use, making it difficult to see the PV cell itself.) Note that if you are able to get a PV panel, they are large and somewhat cumbersome
- Please be aware, regarding the Overhead Image: Modeling Electron Flow in a PV Cell and Circuit:
  - The spacing between chairs and the directions they face are intended to help students visually distinguish the parts of the model
  - The total number of chairs should equal the total number of students in the class. Distribute chairs in approximately these ratios:
  - 12 chairs – silicon in PV cell
  - 2 chairs – electric contact grid on one side of silicon
  - 2 chairs – electric contact grid on opposite side of silicon
  - 10 chairs – electric wire or circuit
- Review the one-page fact sheet about Photovoltaic Solar Power within the student reading Electricity for You and Me and decide if you want to provide it to your class as background reading for this lesson

Suggested Procedure

Part 1: Introductory Discussion

1. Begin by asking students if they can name the most inexhaustible, renewable source of energy known to humankind. (the sun!) State that today the class will learn about one way we harvest the energy of the sun and model this process.
2. Ask if students can identify the two forms of energy that we get from the sun. (light energy and thermal/heat energy) Discuss: Although we understand intuitively that light can travel through space, what about heat? Heat can be transferred via radiation, convection, or conduction. Radiation is the transmission of energy through space via particles or waves. When the sun feels warm on your skin even while the air feels cool, you are experiencing heat transfer by radiation.
3. Ask students to use scratch paper to jot down what they already know about how solar energy is used in homes, schools, businesses, or power plants. After a minute or two for individual thinking, invite students to share with the class. Quickly list several uses of solar energy on the board. Use prompting questions as needed to achieve a diverse list.
4. Remind students that we experience the radiant energy of the sun as both light and heat. Check over the list to identify examples that rely on each. (Most solar electric relies on light energy from the sun, while water heaters and passive solar buildings rely on heat energy from the sun)
5. State that photovoltaic technology produces electric energy from sunlight through a natural phenomenon called the photovoltaic effect. Offer the root words for photovoltaic if you wish. Point out that while all uses of solar energy hold promise for society, we will focus today on photovoltaic or PV energy. If actual solar cells are available, pass them around.

Suggested Procedure *(Continued)*

Part 2: Modeling the Photovoltaic Effect

6. Briefly display the Overhead Transparency/Images: A Photovoltaic Cell and Circuit 1 and 2 and explain that the class will be modeling the photovoltaic effect and the movement of electrons in a PV cell and attached wire or circuit.
7. Next display the Overhead Image: Modeling Electron Flow in a PV Cell and Circuit. Guide students in arranging chairs (or desks) as per the diagram. When the model is complete, ask students to be seated.
8. Distribute scratch paper, one sheet per student, and bits of tape. Ask everyone to make a sign for the part of the model in which they are seated (silicon in PV cell, electric contract grid, or electric wire) and attach it to the back of their chair.
9. Next have students use masking tape to give further definition to the parts of the model. For example, place tape on the floor in a box around the silicon; use tape to link the contact grid chairs to each other; and place a line of tape on the floor along the wire circuit.
10. Explain the parts of the model:
    - The rectangular block of chairs represents silicon, the main material within a PV cell
    - Chairs along the outside of that block represent the electrical contact grids on the front and back of the PV cell
    - The line of chairs represents a wire
    - The wire passes through an electrical device, represented here by a manual bell, buzzer, etc
    - Students, one per chair, represent electrons in the atoms of the materials that make up the PV cell, contact grids, and wires
    - Light aimed at the model from the overhead projector or a flashlight represents light energy from the sun. Emphasize that PV technology uses light energy, not heat energy, from the sun

Suggested Procedure *(Continued)*

11. Begin with all students seated and all chairs occupied. Briefly shine a beam of "sunlight" on one student "electron" in the "silicon." This student-electron, excited by the sunlight energy, moves to the chair of a student seated near him or her. The second student moves to the chair of a third student. This can continue randomly within the silicon until one student moves to the "electrical contact grid." Then student-electron each move forward one chair, along this contact grid and then the wire circuit. The student-electron who moves past the bell or buzzer rings it while moving past. The flow of "electric energy" continues until the circuit is complete, student-electron move through the other electrical contact grid, and the last student occupies the vacated chair in the silicon.
12. Repeat the process in step 11 several times. Challenge students to "flow" smoothly and remind them that this movement of electrons is electric energy. Consider timing the process to motivate students to move efficiently.
13. Emphasize that students are modeling the photovoltaic effect, a natural phenomenon that involves the transformation of light energy into electric energy. Pause to contrast this with other ways in which energy is transformed during the production of electricity.
14. Continue to use flashlight "sunlight" to stimulate electron flow as many times as you judge appropriate for students' understanding.
15. Pause again to briefly display the Overhead Transparency/Images: The Parts of a PV Cell 1 and 2. Define model as a copy or imitation, or a simplified or stylized representation of reality. Guide students in analyzing similarities and differences between our model and a real PV cell. (A real PV cell has more parts. Electrons are only one of the particles comprising atoms. Sunlight energy causes change – an increase in the energy level of electrons in both our model and a real PV system – with the effect or result being an electric current. An electric current really involves the movement of billions of electrons.)

Suggested Procedure *(Continued)*

16. Conclude the lesson by briefly comparing PV technology to other uses of solar energy and other means of producing electricity:
    - The photovoltaic effect is a natural phenomenon involving the transformation of light energy into electric energy
    - Solar water heaters and passive solar buildings use heat energy from the sun, while PV technology uses light energy
    - PV technology can be used at many scales, but however small or large the application, its basic building block is always the PV cell
    - The electricity generated by PV is just like other electric energy and can be used for any of the same purposes
    - PV technology requires no fuel. Because no fuel is burned, use of PV does not generate any pollution (although small amounts of pollution are produced when PV equipment is manufactured, as with any manufacturing)
    - PV cells and equipment have no mechanical (or moving) parts
    - Because there are no mechanical parts, PV cells can operate reliably for years with minimal maintenance and operating costs
    - Energy from our sun is renewable and is the most abundant source of energy known, available in essentially unlimited amounts
17. Pass out the Student Worksheet: Models, Systems, and PV Energy.

Assessment Ideas

Ask students to write a description of how a PV cell and attached electric circuit function as a system. Ask them to illustrate it with some type of drawing or simple diagram. Or ask them to build a model (using sheets of paperboard, string, etc.). Provide a list of vocabulary words that you are requiring them to include, such as photovoltaic, PV cell, silicon, atom, electron, light energy, electric energy, renewable, photovoltaic effect, model, system, subsystem, or others you wish to emphasize.

Extension Ideas

Playing with PV: If functioning PV cells or a PV lab kit are available in your school or district, allow students to experiment with these. (PV cells wired for such use are available from most scientific supply houses. Look for cells with clips on the ends of the attached wires, as these will be more durable than wires alone.) Show students how to make a circuit and use the PV electricity to power a miniature electric motor, buzzer, fan, or light. Compare the use of PV cells for this purpose with the use of miniature hydropower or wind generators.

Learning about PV cells in more detail: Have students do outside research on the other elements present in a PV cell, including how those elements are manufactured so that they contribute to the PV cell's function. Have students present back to the class on their findings.

Where is PV?: Have students make lists of the places around town that they notice PV installations. Have students approximate the size of the PV system (a good average power output for a standard PV panel is 250 Watts, so to figure out the power of an entire PV system, multiply the number of panels by 250W).

ADDITIONAL DOCUMENTS

Student Worksheet: Models, Systems, and PV Energy

Name: _____ Class / Period: _____

Instructions: Please answer the questions below.

1. The most inexhaustible source of energy known to humans is the _____ .
2. The energy of the sun is a _____ natural resource.
3. Sunlight causes a predictable change within a PV cell because of a natural phenomenon called the _____ .
4. Through the photovoltaic effect, _____ energy is transformed into _____ energy.
5. Electric energy is a flow of _____ .
6. A _____ is a copy or imitation, a simplified or stylized representation of a real object or system.
7. A _____ is a set of interacting parts that function as an organized whole.
8. Circle the two subsystems within our model system:
   (a) the sun
   (b) the PV cell, including the silicon and the electric contact grid
   (c) the electric circuit, including the wire and bell (or other "electric" device)
   (d) people (living organisms) and chairs (nonliving things)
9. Circle the one external variable that caused change in our model system:
   (a) electrons
   (b) the photovoltaic effect
   (c) light energy from the sun
   (d) heat energy from the sun
10. Circle two differences between our model of a PV cell and a real PV cell:
    (a) Our model had fewer parts than a real PV cell
    (b) Our model had more parts than a real PV cell
    (c) A real PV cell has billions and billions of electrons
    (d) A real PV cell uses kinetic energy, or energy of motion

ADDITIONAL DOCUMENTS

Student Worksheet: Models, Systems, and PV Energy

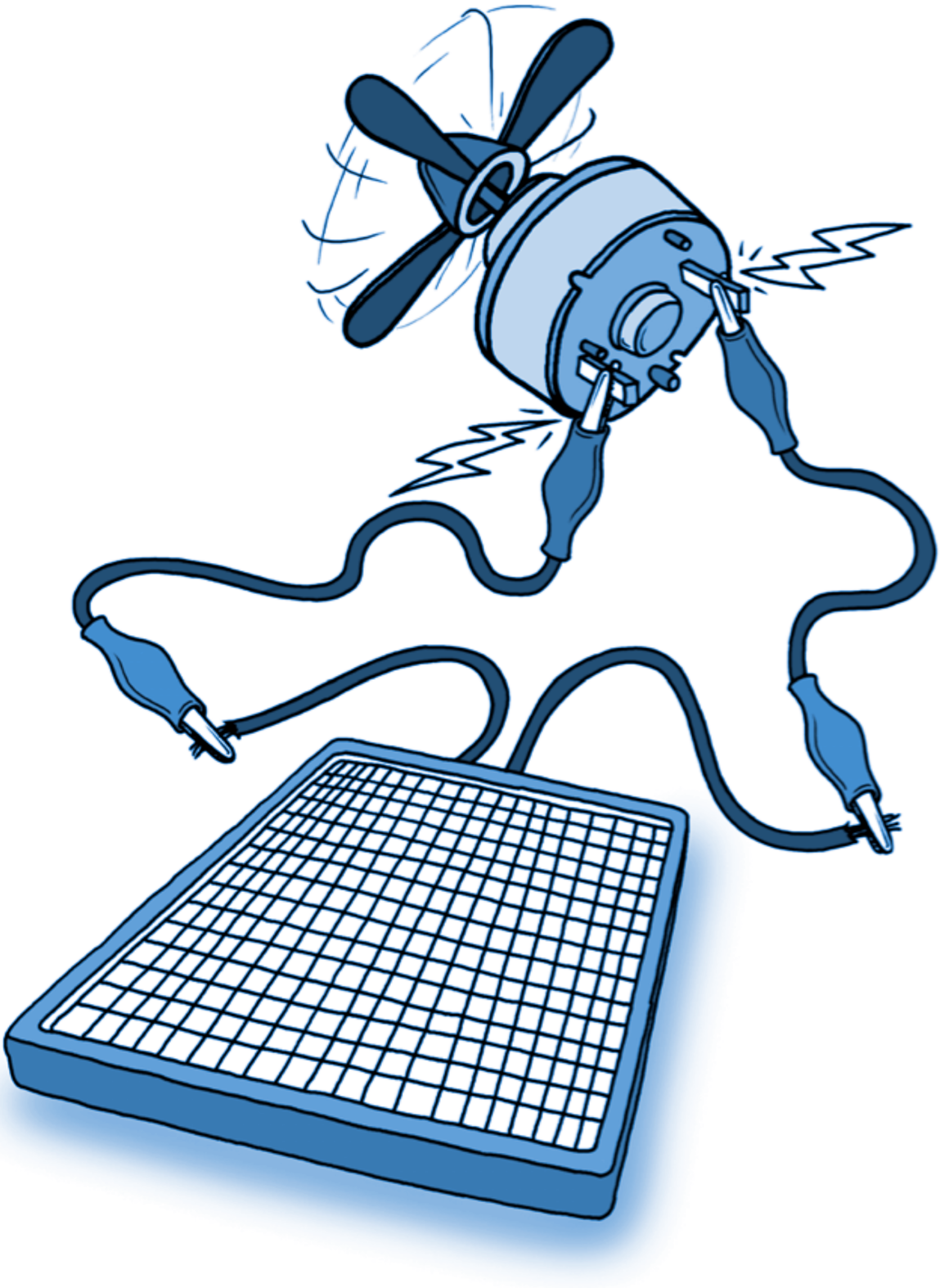
Name: TEACHER ANSWER KEY Class / Period: _____

Instructions: Please answer the questions below.

1. The most inexhaustible source of energy known to humans is the **sun** .
2. The energy of the sun is a **renewable** natural resource.
3. Sunlight causes a predictable change within a PV cell because of a natural phenomenon called the **photovoltaic effect** .
4. Through the photovoltaic effect, **light** energy is transformed into **electric** energy.
5. Electric energy is a flow of **electrons** .
6. A **model** is a copy or imitation, a simplified or stylized representation of a real object or system.
7. A **system** is a set of interacting parts that function as an organized whole.
8. Circle the two subsystems within our model system:
   (a) the sun
   (b) the PV cell, including the silicon and the electric contact grid
   (c) the electric circuit, including the wire and bell (or other "electric" device)
   (d) people (living organisms) and chairs (nonliving things)
9. Circle the one external variable that caused change in our model system:
   (a) electrons
   (b) the photovoltaic effect
   (c) light energy from the sun
   (d) heat energy from the sun
10. Circle two differences between our model of a PV cell and a real PV cell:
    (a) Our model had fewer parts than a real PV cell
    (b) Our model had more parts than a real PV cell
    (c) A real PV cell has billions and billions of electrons
    (d) A real PV cell uses kinetic energy, or energy of motion

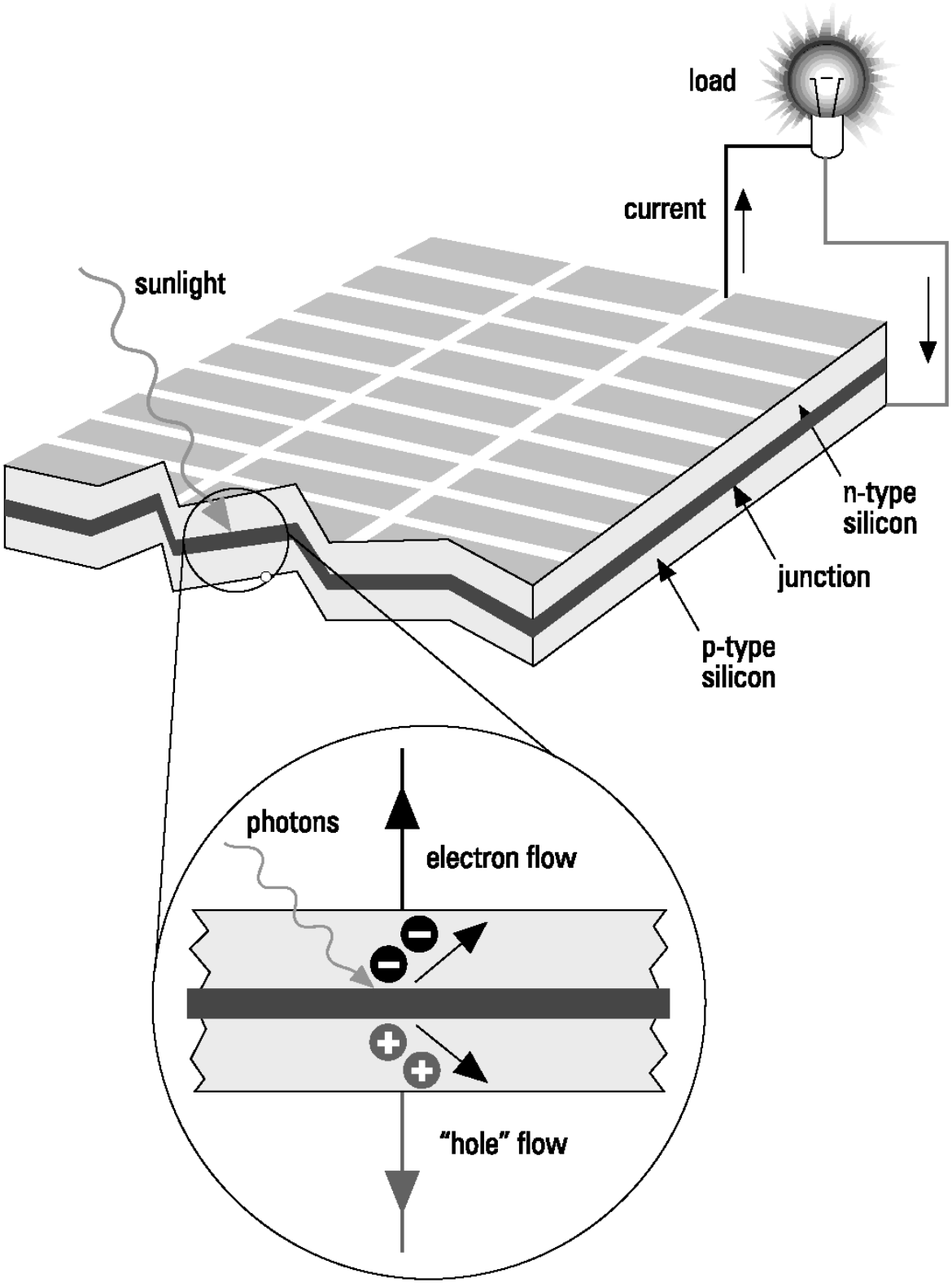
ADDITIONAL DOCUMENTS

Photovoltaic Cell and Circuit Picture 1



ADDITIONAL DOCUMENTS

Photovoltaic Cell and Circuit Picture 2

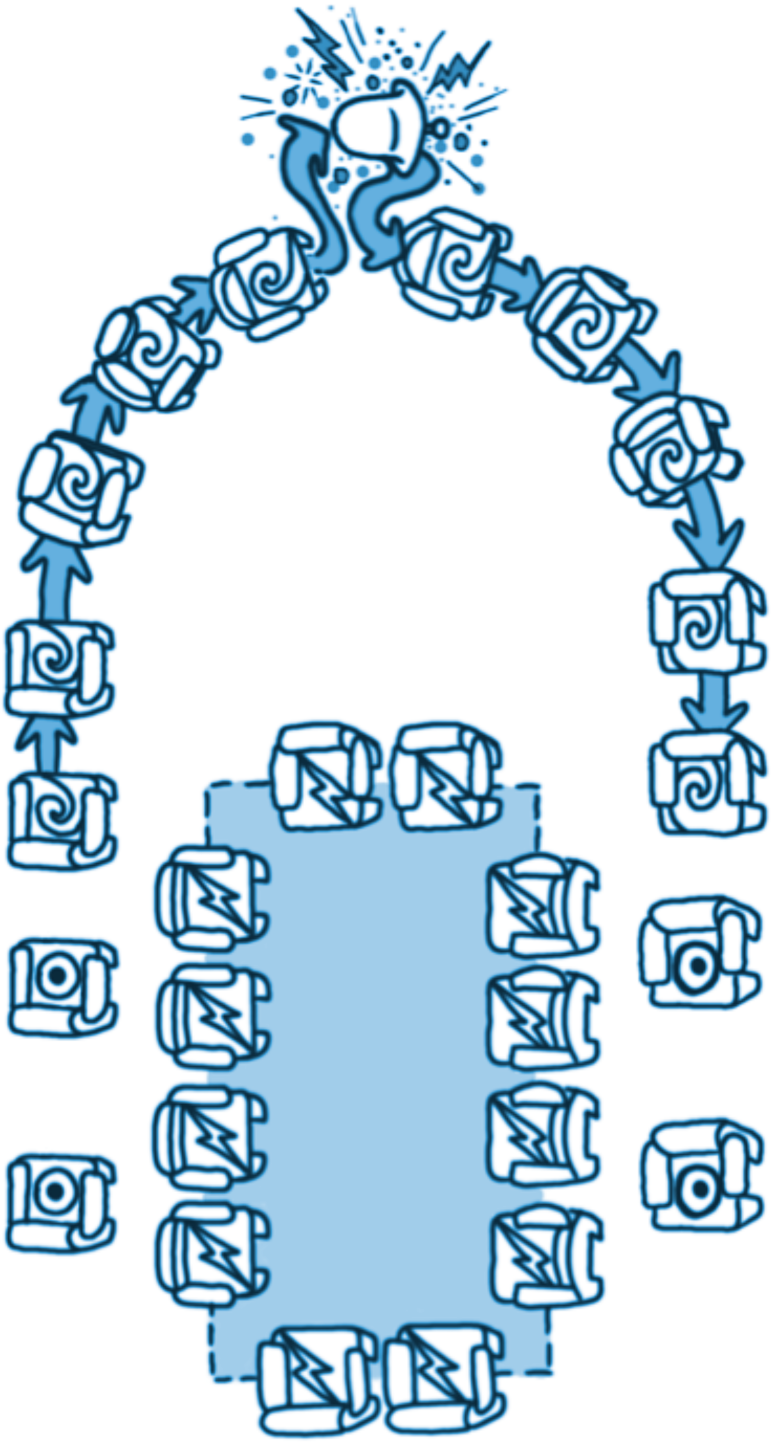


ADDITIONAL DOCUMENTS

Modeling Electron Flow in a PV Cell and Circuit

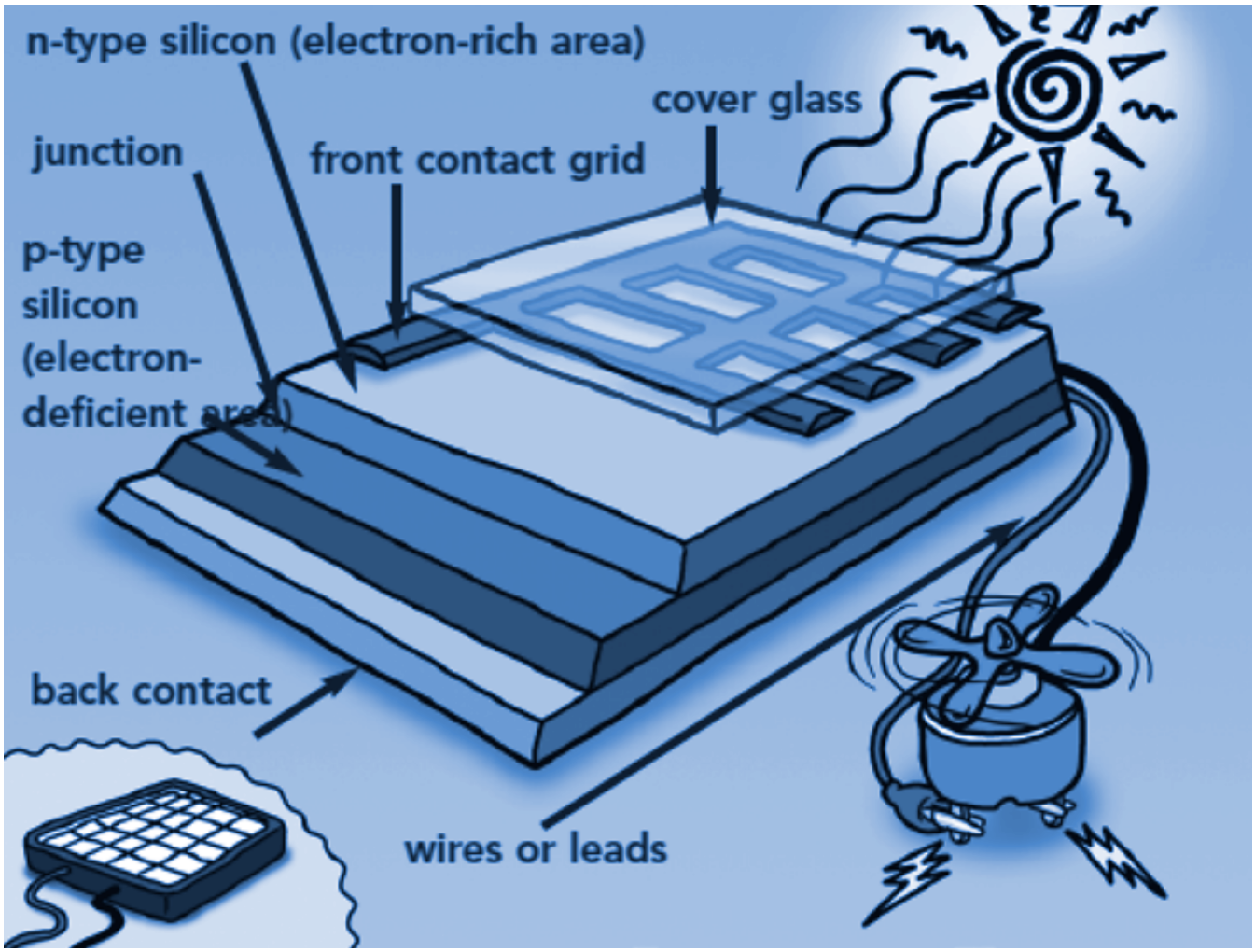
LEGEND

- Silicon inside a PV cell
- Electric contact grid on a PV cell
- Electric wire
- Electric appliance



ADDITIONAL DOCUMENTS

The Parts of a PV Cell Picture 1



ADDITIONAL DOCUMENTS

The Parts of a PV Cell Picture 2