The City Tour for Solar
Learning About Solar Power
Student Guide
Grades 9-12

Photovoltaic Solar Energy:
Exploring the Science and its Potential as a Renewable Energy Resource

Solar Energy Student Guide - Grades 9-12 - Best for Earth and Physical Science Classes

The questions…do you know the answers? If not, you will!

- Do you know the difference between a renewable and non-renewable energy resource, and why this difference matters?
- Have you ever seen a solar panel on a rooftop and wondered how it works?
- Do you know how to generate electricity yourself using solar cells? Do you know what needs to be considered to maximize the electrical output of the cells?
- Do you know how much of the electricity the United States uses today comes from solar energy? From renewable energy resources as a whole? How this came to be?
- Do you understand the implications of energy supply in our world and in your own life?

Background:
You have probably heard a lot of talk lately about energy – the rising price of fuel, shortages in oil supply, and some of the impacts this is having locally and globally. In your own home, a parent may encourage you regularly to turn off the lights or the TV so you're not wasting electricity and the utility bill isn't too high. Perhaps you have also heard about the connection between energy generation and the health of our environment - and about the important issue of climate change. Energy is at the heart of everything we do today. Our nation and most others in the world have become fully dependent upon having it supplied consistently to our homes, buildings, motor vehicles, and more. In fact, our cities, businesses, agricultural practices – *our entire local and global infrastructures* - were designed over the past 100 years with the assumption that energy from fossil fuels would be cheap and plentiful for the foreseeable future.

As they say, "Hindsight is 20-20." There are increasing concerns about the negative environmental and public health consequences, and financial and political costs of extracting and burning fossil fuels such as coal, oil and natural gas to supply our energy needs. Scientists, businesses and others have been exploring renewable energy sources that could provide cleaner, more plentiful, local alternatives, and there are a growing number of solar and other renewable energy applications in place today. However, there are challenges with renewable energy, too, and there is currently no single "magic bullet" solution.

Emerging as a key technology in the race for solutions is electricity from the sun in the form of photovoltaic (PV) technology. The following activities will help you better understand PV technology in a hands-on way and invite you to explore some of the challenges and opportunities of the technology. Perhaps you will be part of the solution someday, as a scientist, engineer, building system designer, architect, or policymaker!

About solar energy:
Solar energy from the ancient past is stored in fossil fuels, such as coal and petroleum. These sources of energy take very long periods of time to form – *millions of years* – and once depleted are nonrenewable within our lifetime. In other words, we can use a gallon of oil or a ton of coal

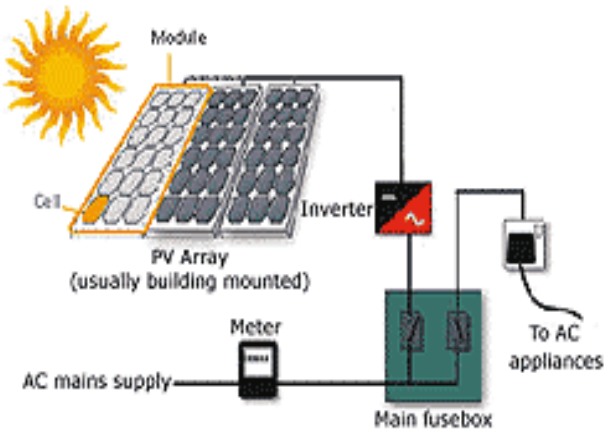
once and then they're gone forever. However, many of the Earth's energy resources are available on a perpetual basis. These include solar, wind, water, and geothermal energy. Other energy sources can be replenished over relatively short periods of time. These include wood and other biomass ("bio" means "life" or "living," so biomass energy is energy from living sources such as corn or grass). All are considered renewable because their source of energy is replaced as soon as we use it, or not long after. Until the early 1900's, we relied on wind and water – renewable energy sources – as our primary fuels. *What do you think happened that caused us to move away from these energy sources?*

Solar power is a synonym of solar energy and refers specifically to the *conversion of sunlight into electricity.* Solar energy technologies harness the sun's power as an energy resource for homes and buildings, and more applications are being researched.

Solar cells or photovoltaic (PV) cells convert solar energy into electricity using the photovoltaic, or *"light energy,"* effect. When light strikes the cell, electrons are dislodged and travel along wires placed within the cell. This flow of electrons is electricity. The PV cell is the building block of solar modules that can be linked together in photovoltaic arrays to supply enough electricity to power whatever load is attached, such as a motor, light, or home appliance.

PV cell performance is measured in terms of its efficiency at turning sunlight into electricity. Only sunlight of certain energies will work efficiently to create electricity, and much of it is reflected or absorbed by the materials that make up the cell. Because of this, a typical commercial PV cell has an efficiency of 15% – about one-sixth of the sunlight striking the cell generates electricity. Low efficiencies mean that larger arrays are needed, and that means higher cost and logistical constraints (for example, the fixed size of a rooftop). Improving PV cell efficiencies while holding down the cost per cell is an important goal towards which there has been significant progress. The first PV cells, built in the 1950s, had efficiencies of less than 4%! The challenge of the PV cell is similar to those first encountered with computers. The first computer was extremely expensive and filled up an entire room; now, we have exponentially more powerful computers that fit in one hand and can be afforded by millions of people. Imagine if we applied this same ingenuity and level of effort to the science of photovoltaics!

A photovoltaic energy system that would be used to provide electricity to a school, building or home is made up of several major parts, including:



1. Sun – energy source
2. Photovoltaic Modules (series of connected PV cells) — these convert sunlight directly into electric current. Like batteries, the current they produce is direct current, or DC.
3. Inverter — the inverter changes the DC electricity produced by the modules into alternating current, or AC, electricity for use in a home or building.
4. Transformer (not picture) — the transformer changes the voltage of the electricity coming from the inverter to match the voltage of electricity that is used in the building.
5. Electrical Distribution Panel (see Main Fusebox)

— the electrical energy produced by the solar electric system is connected with the home or building's electric system at the distribution panel. This allows solar energy to be used for lighting, computers, and other electric loads.

6. Electric meter – the electric meter keeps track of the amount of electrical energy produced by the solar photovoltaic system. Electrical energy is measured in *kilowatt-hours*. If more electricity is produced than is needed by the home or building, and the system is connected to the grid, then the electricity can be sold back to the electric utility!

Activity 1: Scientific investigation of conditions that influence PV cell performance
You will get to interact with PV cell by developing your own hypotheses and conducting a scientific investigation to see for yourself how various conditions impact the electrical output of PV cell.

Worksheets for this activity:
Will be provided by your teacher and are at www.need.org/needpdf/PhotovoltaicsStudent.pdf.

Conditions to investigate:
The conditions you will test may include but are not limited to:

- The angle of a PV panel to a light source
- The distance of the PV panel from a light source
- PV cell in partial shadow
- Color of the light source
- Impact of concentrating light from a light source
- Air temperature

Materials needed to explore the above conditions:

- PV panel
- Multimeter
- Light source
- Protractor
- Lamp
- Tape Measure
- Piece of dark cardboard or construction paper
- Color filters
- Magnifying lens
- Thermometer
- Light source and hair dryer
- Alligator connectors

Activity 2: Our Energy Sources - **Cooperative online research and group presentations**
Research and discuss the contextual and scientific landscape of solar energy in the United States.

- As directed by your teacher, break into small groups to conduct research on the following questions. Each group will tackle 1-2 of the questions below. Divide the work to be sure that all of your group's questions (and sub-questions) are answered. If there are more questions your class would like to investigate, please add them!
- Each group will present their findings to the class in the order that they've been asked below. This will allow everyone in class to gain an understanding of the U.S. electricity supply and solar energy's part in it, the challenges and opportunities of PV technology, and the implications of the technology for the future.

The questions:

1. What is the percentage breakdown of fuels supplying the United States' current electricity needs? How much is coming in total from fossil fuel sources? Nuclear? Renewable resources? Solar specifically?

2. Why does the US burn fossil fuels to meet the majority of its electricity needs? What do we know today about the effects of burning fossil fuels that wasn't known when they first emerged on the scene in the late 1800's?

3. What are the benefits and limitations of using solar power to provide electricity for our country? (Apply lessons from Activity 1)

4. What is the connection between PV electricity and energy efficiency in a home or building setting? Why is this important? What does this imply needs to be done in addition to advancing the technology of solar cells?

5. In addition to solar electricity, what are some of the realistic ways we can limit our use of fossil fuels and reduce our dependence on them?

Sources for more information:

- Basic solar: http://www.eia.doe.gov/kids/energyfacts/sources/renewable/solar.html
- Solar cells: http://www1.eere.energy.gov/solar/solar_cell_materials.html
- Photovoltaics: http://www1.eere.energy.gov/solar/pv_basics.html
- Brief history of solar: http://www.azsolarcenter.com/education/renewable011199.html