Designing a Solar Amusement Park

Subject: How can we use the engineering design process to create the greatest amount of renewable electricity possible?

Grade levels: 4th-8th grades

Prep Time: 15-30 min

Lesson length: 90 min

Teaching Location(s): outdoor

EFI to Group Size Required Ratio: 20:1

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Students are introduced to the world of creative engineering product design. In this activity, teams work through the steps of the engineering design process by completing an actual design challenge presented in six steps. As members of an engineering design team, students choose a theme park ride that they want to build that is run ONLY by a solar panel and simple motor. As students begin defining the problem, they learn to recognize the need, identify a target population, relate to the project, and identify its requirements and constraints. They gather background information (e.g., remember a previous experience on a ride, conduct interviews with potential "customers" about what they like best in a park ride, use Google to gather information), brainstorm alternative solutions, evaluate possible solutions, create and test prototypes, and re-design to optimize their solutions.

Objectives

- *Explore how a solar cell works using a simple fan motor and multimeter.*
- *Design and build a spinning solar powered theme park ride.*
- *Understand the importance of creating detailed design plans and the use of the engineering design process.*

Preparing for Instruction

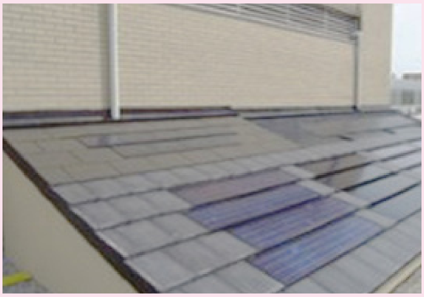
Before beginning the solar park activity, a simple lesson on how a solar cell works is strongly recommended. Students need to understand the basics such as placement of the solar cell for maximum power efficiency before building their ride. The instructor can then identify and address any misconceptions about how PV cells work.

Instructor Content Background Information

A photovoltaic cell converts radiant energy from the sun directly into electricity. Photovoltaic (PV) cells use materials called semi-conductors. When solar radiation falls on these materials, one side of a plate becomes positively charged while the other becomes negatively charged, creating a potential difference. These oppositely charged plates create a flow of electrons, or electricity.

Three types of solar panels are available: monocrystalline silicon, polycrystalline silicon (or multicrystalline silicon) and amorphous silicon (or thin film). Monocrystalline panels are the most efficient (15-18%), followed by polycrystalline panels (12-14%), then thin film (5-6%). Monocrystalline panels use individual cells to make up a module, while a polycrystalline panel is solid with flake-like pieces of silicon pressed together. Thin film comes in flat, thin, flexible sheets.

Although solar arrays are a way to free a building from fossil fuel energy, some building and homeowners do not like the appearance of roof-mounted systems (see figure below). Building integrated photovoltaics (BIPVs) use thin film technology to incorporate the PV paneling into building materials such as roofs, façades, awnings or covered walkways (see figure below), so they are hardly noticed.



Since the amount of electricity produced by PV cells is related to how much sunlight it receives, it is important to mount the panels on a surface that receives direct sunlight and is not shaded by trees or other buildings. An array has the greatest output when mounted on a roof that gets a lot of sun (in the northern hemisphere, this means a south-facing roof). An array on a roof can be angled to take advantage of how the earth tilts during its orbit around the sun.

Materials

- Materials part 1:
  Solar cell (suggested 1V, 400 mA)
  Hobby motor with fan blades (suggested 1.5 to 3.0 Vdc, at 330 mA)
  Multimeter
  Lab sheet
  Science notebook and pencil (1 per student)
- Suggested Building Materials part 2:
  (Required) All Materials from Part 1
  (Required) Plastic round attachments for spinning
  Styrofoam and/or plates, bowls, cups
  Plastic silverware
  Toothpicks
  Party hats
  Glue and tape (all kinds)
  Wooden dowels or skewers
  Toothpicks
  Erasers
  Disposable pie tins
  Straws
  String or yarn
  Pipe cleaner
  Q-tips
  Bobby pins
  Large white board and dry erase markers
  Dollar store toys (miniature cars, princess rings, etc. – must be lightweight)

Word Bank

Solar (PV) cell Multimeter Circuit Engineering Design process
Constraint Shading Architectural engineer Electrical engineer
Solar array Solar Power Blueprint

Instructions

Introdution (30 mins)

Use your introduction to spark ideas and connections, stimulate wonderment and excitement. Show students a small solar panel. Use some discussion prompts so students can relate their existing knowledge to how solar panel works. Example dialogue:

This device is called a solar panel. It is sort of like a battery, but instead of storing chemical energy, it converts the energy we get from the sun (known as *radiant energy) into electricity (or electrical energy). When a house or building uses a row of two or more solar panels, we call this a solar array. We see many homes in Arizona with solar panels. Where are the panels usually located? (On the roof.) Why do you think that is? (The roofs of buildings are exposed to the greatest amounts of sunlight and are better than the ground for being clear of any trees or other buildings that might cause shade.)*

Here is a solar panel. Is it working right now in the classroom? (Students will say no, but it actually will put out a low voltage in the classroom.) But, there is light in this room, so why is the panel not working?

Measure the voltage of the panel. If you're inside, the light might not be intense enough to create electricity and you will need to repeat the measurement outside. If sunlight is unavailable, a 100-watt incandescent lamp provides enough radiation for each mini solar panel.

As it turns out, this light is not intense enough to create electricity. Let's go outside to see how it really works! (Take the class outside for a short demonstration.)

Have students create a circuit using the fan motor and solar panel. Have them measure the voltage of the panel outside and compare it to what it was inside.

Now we see the panel is working! This direct sunlight is perfect for creating electricity! Notice how the tilt of the solar panel and the direction the panel faces affects the brightness of the light bulb. Which direction is best? Have the students make several observations and take measurements of their panel in different directions. (Answers: In the direction of direct sunlight, which is east in the morning, west in the afternoon, south at midday, and towards the south in general.) So if you were an architectural or building engineer, where would you place the solar panels? (Answer: On a south-facing sloped roof or overhang of a building.) Great!

Planning and Designing the Solar Park Ride (30 min)

Give students time to explore and discover, to gain some experience. Have students create detailed design plans. Students will be swapping design plans; each group will build a park ride designed by a different team. Therefore, it is important that their plans be clear and complete.

1) Present students with the engineering design challenge: Design and build a spinning solar powered theme park ride that will be a major attraction in a solar amusement park.
2) Review requirements, constraints, and available materials.
3) Review the design swapping plan and discuss the importance of detailed design plans. Help students recognize the importance of professional communication in engineering design, using oral speech, written language, and charts, graphs, and sketches. Engineers work on teams with diverse members. Everyone on a team might have different about different aspects of a design. Engineers also work with customers who need to know what they are doing.
4) Allow students time to plan and sketch.
5) Swap design plans and allow groups to talk to each other and ask questions about the plans they have been given. Discuss with students procedures for getting approval to make design modifications. (Emphasize that all modifications should be minor in scope and stay true to the original design).

Before beginning the "planning" process review with the students the engineering design process. Emphasize to the students that all engineers use some form of the steps of the engineering design process to organize their ideas, and test and refine potential solution to real- live challenges. Students must be able to work together in teams. Theme park engineers work together- both architectural design engineers as well as mechanical or aerospace engineers come together to build some of the world's tallest and fastest rides. Millions of people may experience your rides, and their safety depends on your design details and building specifications.

Building and Testing the Solar Park Ride (45 min)

Focus on the iterative nature of the building and testing phases of the engineering design process. Instructional Sequence:

1) Allow students to build, test, and revise.
2) Have a board meeting allowing students to report out on the status of their rides as a work in progress. This is particularly important for those whose rides are not working. Getting constructive feedback from the class is extremely rewarding.

Share with the students that as their ride's construction advances, they may find that some elements of the ride are not working properly. Tell them that they must be willing to adjust their design plans throughout the building phase. Iterative cycles of brainstorming and testing are part of the design process. Prior to the ride's debut, the engineers coordinate numerous test runs and monitor the ride's safety. Many engineers act as guinea pigs, being the first passengers to experience their attraction.

Reflection (15 min)

Making meaning and reflecting on the activities is a very important aspect of learning. Have students analyze observations or data, construct explanatinos, and make ties to content, as well as reflect on the learning. You can organize a gallery walk for this:

1) Have students show off their rides to the public.
2) Have the original "blueprints" to show how the ride was created and modified.

At the end of the gallery walk bring all the groups back together and have a discussion that addresses these questions:

- What were some of the challenges your group faced?
- How did you overcome those challenges working as a team?
- What are some "rules of thumb" you would suggest to other teams designing building solar-powered products?

Connect beyond the classroom (10 min)

Do you think all schools, houses, libraries and supermarkets in every part of the world have electricity? As it turns out, many countries suffer from what is sometimes called "energy poverty." When no electricity is available or when an electricity shortage exists in a city or town, we say this area suffers from energy poverty. This happens because a country cannot afford or does not have enough resources to create all of the electricity it needs. Sometimes these areas are without power for hours or days! Some places exist without any electricity at all! Can you imagine what it would be like to wake up in the morning and not have any electricity? What would school be like without electricity? Do you think these areas could benefit from using photovoltaic panels?

Assessment Opportunities

Have groups make class presentations about their park rides. Require each student to participate. Require groups to describe how their rides work and why they made certain material/design choices. Also have the students explain how the solar panels were integrated into the design of their rides.

Deepen your Knowledge

Maps like the ones below could be used to help students reason about the question above: Do you think these areas could benefit from using photovoltaic panels?

- World energy map: http://www.energyhii.com/userfiles/images/437503_1--world-map.jpg
- World energy consumption map: http://burnanenergyjournal.com/how-much-energy-are-we-using/
- World solar energy map: https://s-media-cache-ak0.pinimg.com/736x/ca/88/84/ca8884a29211c8e14afb02c2d6168211.jpg
- Global solar irradiance map: http://www.vaisala.com/en/energy/support/Resources/Pages/Free-Wind-And-Solar-Resource-Maps.aspx
- Solar energy potential - find yourself!: http://www.renewableenergyst.org/solar.htm


Solar Amusement Park Reflection

Questions to think about:

1. What worked, what didn't work with your design?
2. If you could change one thing about your design what would it be?
3. If you could have 1 "dream" material that you didn't have what would it be, and how would you use it?
4. Did your ride spin? If so, why do you think you were successful? If it didn't, what could you have done to improve it if you were given more time?

Next Generation Science Standards

Grade 4–8

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.

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

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

5-ESS3-1: Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment.

MS-PS3-3: Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.

MS-ETS1-2: Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

MS-ETS1-3: Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

Adjustments (Focus) for Grade Levels

Scaling of this activity depends on the amount of interaction between the students and the teacher during the design and building process.

For advanced students, offer little to no advice and have students research different options so that they develop their own designs. Do not restrict their choice of materials or even offer examples of different devices. Have these students independently test their designs by designing their own experiments and ask them to justify their design choices either through a presentation or paper. For students who need more help, interact with them through every stage of the planning and building process. Suggest the materials to use or restrict them so they do not have to make as many choices. Offer a variety of examples or simply instruct all the students to construct their ovens based on a provided design and instructions.