Environmental Science Institute
UNIVERSITY OF TEXAS AT AUSTIN

LESSON PLAN – Solar School Detectives

Title of Lesson: Solar School Detectives
Description of class: Middle School science
Length of Lesson: 90 minutes
Purpose: The goal of this lesson plan is to familiarize students with basic concepts related to solar arrays. Driving this discussion will be the final question, should their school build another solar array or not?

Objectives: Students will be able to:
- **(a)** Explain the atomic properties of Silicon, Boron and Phosphorus that make them suitable for use in Photovoltaic Solar cells
- **(b)** Explain what electricity is and describe the movement of electrons in a solar cell
- **(c)** Analyze data in graphs and draw conclusions

Equipment and Supplies: A copy of the Solar Lesson Plan Worksheet for each student. Three (3) or more solar race car toys, Two (2), or ideally more, small solar panels with voltmeters and inclinometers., Access to a computer and the internet (infinitepower.soltrex.com).

TEKS:
§112.16. Science, Grade 5, Beginning with School Year 2010-2011.
a. Introduction.
4) In Grade 5, investigations are used to learn about the natural world. Students should understand that certain types of questions can be answered by investigations and that methods, models, and conclusions built from these investigations change as new observations are made. Models of objects and events are tools for understanding the natural world and can show how systems work. They have limitations and based on new discoveries are constantly being modified to more closely reflect the natural world.

(B) Within the natural environment, students learn how changes occur on Earth's surface and that predictable patterns occur in the sky. Students learn that the natural world consists of resources, including nonrenewable, renewable, and alternative energy sources.

b. Knowledge and Skills
(2) Scientific investigation and reasoning. The student uses scientific methods during laboratory and outdoor investigations. The student is expected to:

(D) analyze and interpret information to construct reasonable explanations from direct (observable) and indirect (inferred) evidence; and

(F) communicate valid conclusions in both written and verbal forms.

(3) Scientific investigation and reasoning. The student uses critical thinking and scientific problem solving to make informed decisions. The student is expected to:

(A) in all fields of science, analyze, evaluate, and critique scientific explanations by using empirical evidence, logical reasoning, and experimental and observational testing, including examining all sides of scientific evidence of those scientific explanations, so as to encourage critical thinking by the student;

(D) connect grade-level appropriate science concepts with the history of science, science careers, and contributions of scientists.

(8) Force, motion, and energy. The student knows that energy occurs in many forms and can be observed in cycles, patterns, and systems. The student is expected to:

(A) explore the uses of energy, including mechanical, light, thermal, electrical, and sound energy;

Engage (5 mins): Stimulate students thinking about solar energy by asking them where they have seen solar panels recently. Additional questions to stimulate initial thinking could be:
How do you expect energy production to vary over the year?
Would solar energy production ever be zero? If so, why?
Pull out solar race car and solar panel as demonstration of specific solar devices. Questions which could be asked about the panels include: Which of these panels do you expect can produce the most energy in a month? Change the orientation of the solar panels and ask how much energy the panels will produce now. Explain that we are going to explore solar energy in the class and go outside and use the solar equipment before we decide whether the school should invest in another solar array. Ask the students what questions they need to ask in order to determine whether the school should build another array. Questions might include: How much does a solar array

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cost? How much energy does it produce? How does this energy production change daily, and during the course of the year? Explain that the worksheet will help to answer many of these questions.

Expore (25 minutes): To cover questions before the students do the worksheet, explain that two important concepts are 'power' and 'energy.' Ask the students if anyone knows what the difference is between energy and power. **Energy** is the ability of a system to do work. However, it seemed more useful to discuss how energy can be thought of as existing in everything (matter, heat, solar energy) as a discrete quantity. This helps to make sense of the definition of power, being the rate at which energy is used (or changes form). The best analogy found for the idea of power is to talk about race cars and trucks that have powerful engines so that they can use energy faster. For solar panels, **power** is what is produced at any instantaneous moment as the sun shines on the array. The cumulative amount of power that is produced over a given time is the energy that the solar panel creates.

If possible, point out the O'Henry solar energy station outside the classroom. Explain that we are going to look at some data that show the power and energy that the station has produced, and that this information will help them decide if the school should build another solar array. Hand out worksheet and have the students go over them together in their groups. Questions on worksheet will pertain to various data charts showing the solar energy production on an hourly, daily, or monthly basis.

Explain (10 mins): Regroup and have the students explain the answers to their classmates.

Elaborate (5 mins): Problem 4 pertains to how seasonal changes in energy production are partly related to the change in the angle of the sun. Elaborate on how this is akin to holding the solar panel at different angles in relation to the sun on a single day. It helps to ask a student to volunteer to be the sun, while the instructor holds the solar panel at different angles to the student to demonstrate the importance of angle. Remind the students how the sun changes position in the sky seasonally. Connect the dots between this seasonal change and the change in solar energy produced during the year.

Also, ask the students if they remember the weather from two summers ago and last summer. Some students may recall that 2007 was an extremely wet summer (remind them how Barton Spring Creek was flowing all year), while 2008 was extremely dry. Draw their attention to the difference in solar energy output between 2007 and 2008 on Figure 1 of their worksheet.

Outside Activities (30 mins = 10 mins x 3 groups) Divide the students into three (3) groups and explain that they will work with their group outside to finish the worksheet. Group 1 will start with the solar panels, Group 2 with by describing the O'Henry Solar Array, and Group 3 by experimenting with the Solar Cars.

It helps to have two instructors (or even three) given that there are 3 different groups. With 2 instructors, explain to Group 3 that they should read their worksheet and answer questions 14 and 15 and you will spend the last 5 minutes of their time talking about the solar array with them. The instructor should then spend the first 5 minutes with Group 1, making sure that they understand how to use the solar panels and equipment to measure voltage and current. This brief explanation only takes a minute or two.

If another instructor is available, they should monitor the students with the solar race cars to provide some structure to their experimenting. The students in this group will be timing the speed of the solar cars when the solar panel is tilted at different angles. Their goal will be to find the best angle such that the cars go the fastest.

Potential Student Questions & Answers: How expensive is the solar array? ~$30,000 (order of magnitude at least). A good rule of thumb is <$10 (usually $7) per Watt. An array to power an entire house is usually less than $20K, without rebates. How much power is it producing right now? The range was between 500 and 2,000 W depending on the amount of sun. For comparison, explain that a common light bulb needs 60 W of power. Note: On the cloudy day, students did not find a $30,000 solar panel that can light 10 light bulbs to be very impressive. Can the solar panel rotate? No, it is in a fixed position. Why can't it rotate? Presumably because it would have cost more money to do so.

Evaluate (5 mins): We regroup one final time (outside) after all the groups have gone to ask everyone what angle was the best? How does this angle compare to the angle of the O'Henry solar energy station? Is there a better angle (i.e. try to steer them to consider the idea that a better set-up would make the solar panel rotate to continually face the sun at an optimal angle). Finally, ask the students whether they would build another solar panel at the school. If there is enough time, students could discuss this idea in their groups first and then debate the question as a class after each group decides.

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Additional Notes - Solar School Detectives

The data used in the Solar Lesson Plan Worksheet is for O'Henry Middle School in April 2009, when the lesson plan was first created and taught. To obtain more recent solar data for your school, follow the easy steps below.

1. Go to www.infinitepower.org
2. Scroll down and choose the link "Projects" from the list on the left (note the other available resources on this page).
3. Select the link "Solar for Schools" (again, note the other available resources on this page).
4. Scroll down and select "Enter our Solar Portal" – you should be at the url, infinitepower.soltrex.com
5. Select the "Building" Tab from the front page.
6. Select the school whose information you want, for instance, Bryker Woods Elementary School. Now the page shows you information on their solar array and the latest solar data available. To download information to create your own graphs, you need to clink on the "My Account" tab and register.
7. Once you log in, select "Create Customized Graphs and Charts" and follow the steps below to create various graphs. Below each graph is a link to "Download all available data for this system in this date range (Excel)"
8. You can now create custom graphs in excel from the data that you downloaded.

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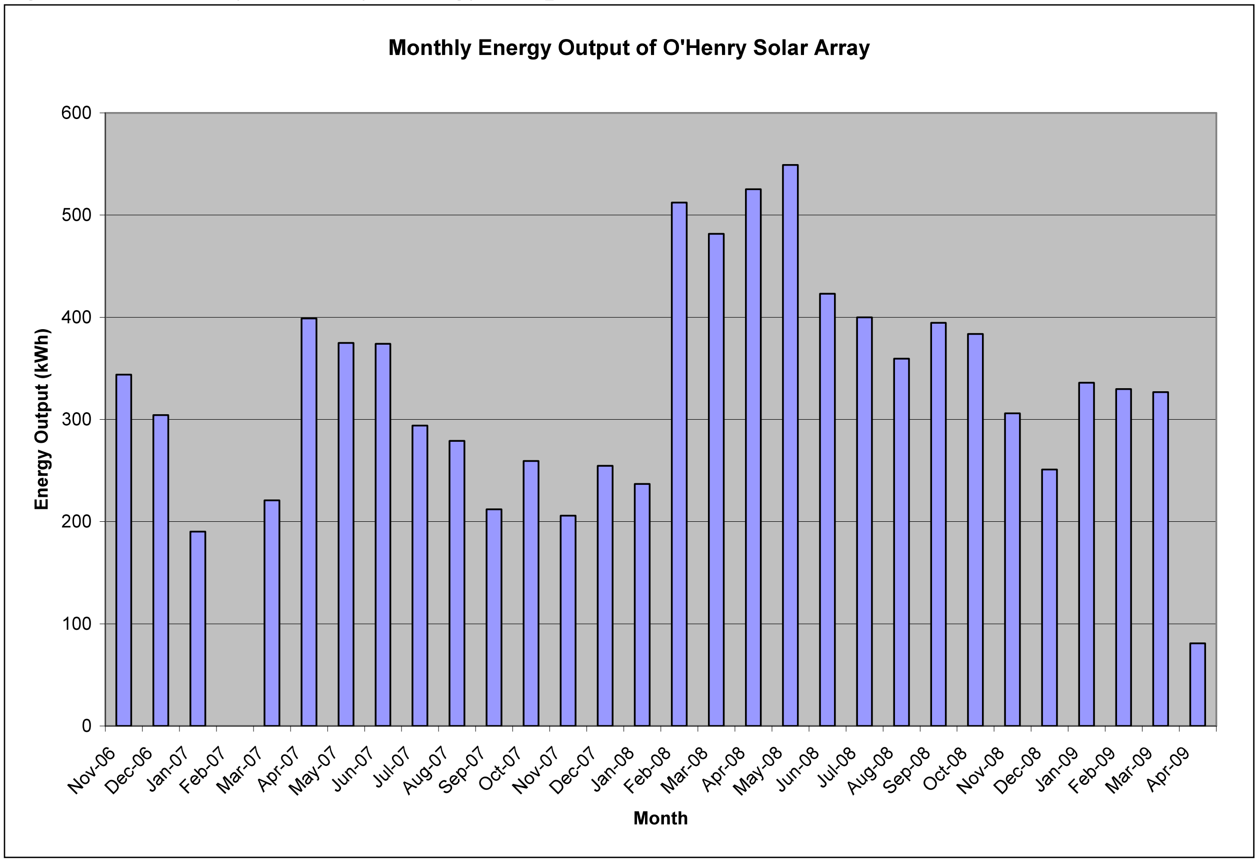
WORKSHEET – Solar School Detectives **Name:__________________**

1. The graphs below display either power output or energy output from the O'Henry Middle School Solar Array. What is the difference between power and energy? (See last page for information to adapt this to any school.)

Figure 1: O'Henry Monthly Energy Output



In the graph above, we see the energy produced for every month since the solar array was installed in November of 2006.

2. Why do you think no solar energy was produced in February 2007? How might you confirm this guess?

3. During what months does the energy produced tend to be higher than average?

4. Why do you think the energy produced changes throughout the year? List at least 2 reasons.

Figure 2: O'Henry Daily Energy Output

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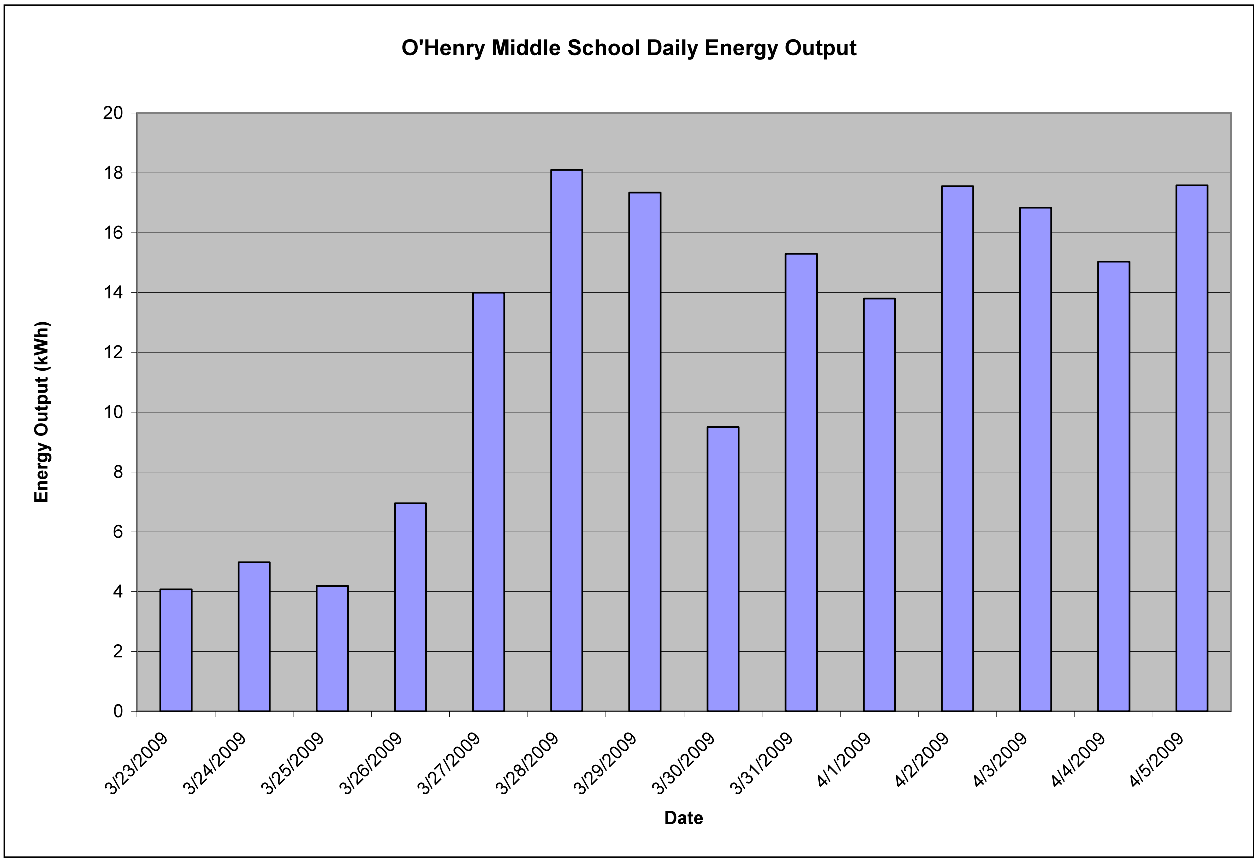


In the graph above, we see the energy output displayed for the past two weeks.

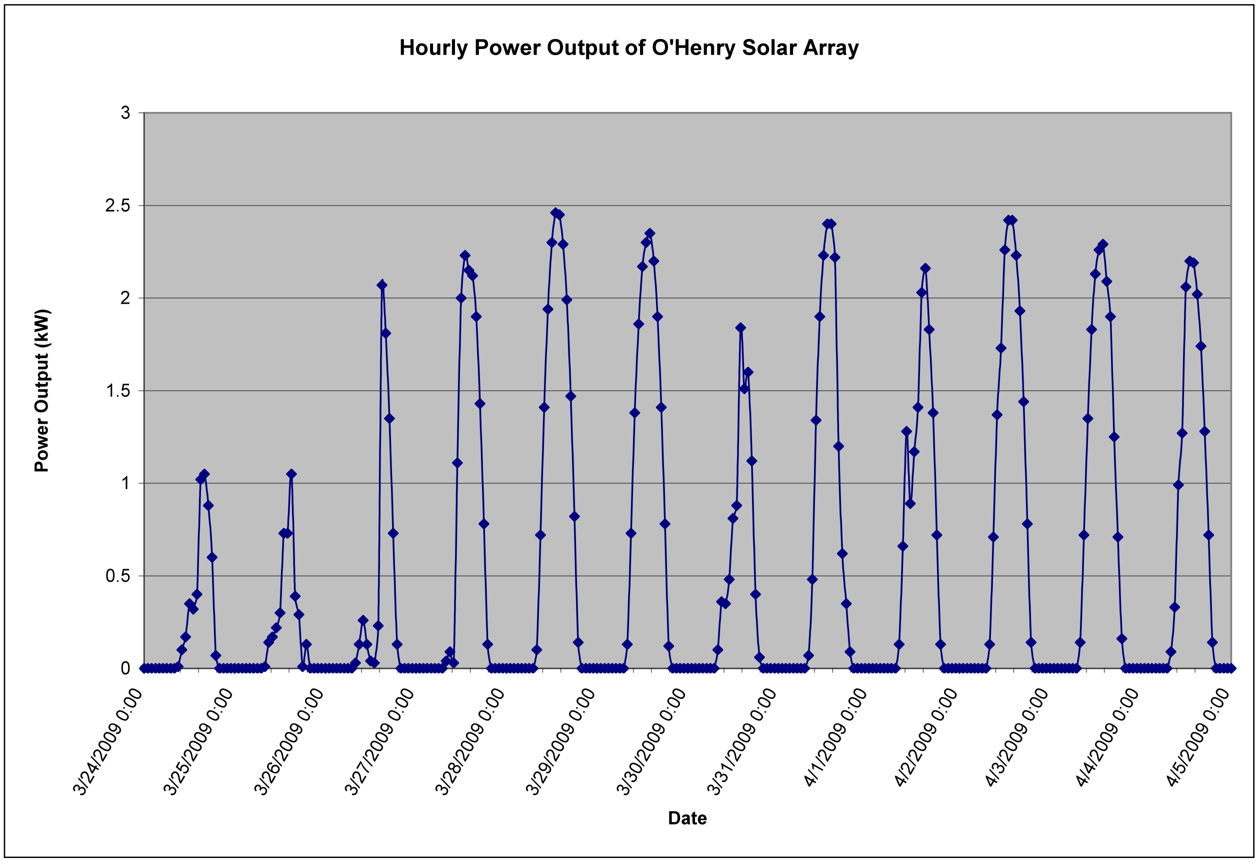
5. Look at Figure 2 above and Figure 3 on the next page. Is there a correlation (relationship) between power output and energy output? If so, what is it?

6. On what day was the most energy produced, and how much energy was it?

7. On what day was the least energy produced, and how much energy was it?

8. For the lowest energy producing day, how much energy was produced as a percent of the highest energy producing day?

Figure 3: O'Henry Hourly Power Output



In the graph above we see the power output displayed for two weeks in April of 2009.

9. Explain why there are peaks (high points) of power output separated by times when no energy is produced.

10. How does the power output on March 24th and March 25th compare with other days? Why do you think this is the case?

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Outside Activities:

Solar Panel: Try holding the solar panel at different angles to the sun and see how the current and voltage change.

11. What is the maximum amount of current (amps) that can be produced? What is the angle of the solar panel for the maximum current?

12. What is the maximum amount of voltage (volts) that can be produced? What is the angle of the solar panel for the maximum voltage?

13. Given that Power (watts) = Voltage (volts) x Current (amps), how much power can the solar panel produce?

Large O'Henry Solar Array: This Solar Array is angled at 30º, and can produce up to 4.5 kW of power. Over the 2.5 years since it was built it has produced 9,715 kWh of energy, the equivalent of 15,000 miles worth of CO_2 emissions from the average American car.

14. Describe the solar panel in front of you. Try to be as specific as possible about what you see. Try drawing a sketch on the back if it helps.

15. Think of 3 questions that you have about the solar panel array in front of you.

Solar Cars: Try operating the car in both the shade and the sun. Try tilting the solar panel at different angles. Using the measuring stick and chalk, measure a 10 foot length on the sidewalk. Using your stopwatch, measure the time it takes the solar car to travel this distance.

16. How fast (ft/s) did the solar cars travel? If there are 5,280 ft in a mile, what was the cars speed in miles/s? miles/hour? Did the cars go faster when the solar panel was oriented at a certain angle? After you measure the solar panel angle in Questions 11 and 12, do you find that the solar car is fastest at a similar angle?

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17. Do you think that O'Henry Middle School should build another solar array? Defend your answer by including a discussion of that amount of energy and power the current system produces, versus how much the system cost to build.

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