www.qesst.org

Title: Atmospheric Effects on Solar Panels
Subject Area: Science
Unit Duration: Two to four class periods
Focus Grade Level: 6th grade
Grade Level Range: 5th-8th Grade

In this lesson, students experiment with various materials that diffuse light in order to represent how the atmosphere above different cities can hinder the efficiency of installed solar panels. To start off, students brainstorm ideas on how solar panel are different in space versus solar panels on Earth. From this discussion, students then understand that the Earth's atmosphere changes the efficiency of solar panels here on the surface. Students then create filters to go above solar panels to represent atmospheric conditions in different cities around the world, giving their reasoning as to why they chose different materials for different atmospheric conditions. Students will also use a multimeter to investigate how their block has affected the output of their solar panel. Finally, they will compare data across blocks.

During this unit, students have the opportunity to participate in the following

- Engineering Systems: using the tools of engineers, participating in an engineering community, etc.
- Engineering Research Processes: Design, Run Experiments, Analyze Results
- Engineering Communication Processes: Communicate about own work, communicate about others' work, read the literature (collective knowledge of the field)

MATERIALS & EQUIPMENT

One solar panel per group

- One light source per group (or do this activity outside)
- Multiple materials with which to filter and/or block the light
    - Translucent tissue paper
    - Tracing paper
    - Mesh screens of various densities
    - Frosted glass
    - Different gauges of vinyl fabric, available at stores such as Jo Ann (examples here)
- Scissors
- Computers or laptops for research
- One multimeter per group for data collection
- Worksheet (provided below) to record research and data

PREREQUISITE STUDENT KNOWLEDGE

Students should be aware of what solar panels are and have a general knowledge of how solar panels work (i.e., light shines on them and produces electricity). If not already taught, teachers can consider using the following lessons: Sunlight has Energy, Young Scientist Pilot Line, Solar Cell Discovery, Electron Chairs, Ella the Electron, Construction Paper Solar Cell. Students should also know what the atmosphere is and that there are particulates in the atmosphere. These particulates can include smoke, pollution, liquid droplets, dust, soot and pollen, among other things. Finally, students should know how to use a multimeter.

LEARNING OBJECTIVE(S)

- Students will be able to identify and design a model to represent atmospheric effects on solar panels.
- Students will be able to write a defense of how their blocks demonstrate the atmospheric effects on their solar panel of a specific city around the world using data from a multimeter.

WORD BANK

Solar panel	A device that uses the radiant (light) energy from the sun to create electrical energy
Atmosphere	Layer of gases surrounding the Earth
Pollution	Contaminants/particles in the air that can cause negative effects
Multimeter	An instrument used to measure current, voltage and resistance

Introduction/Motivation

The teacher leads the students in a discussion about the differences between solar panels in space and solar panels here on Earth. Students will realize that there a many differences, however the teacher should direct students to the fact that the atmosphere obscures the light getting to the solar panels on Earth. Once students have grasped this idea, the teacher will then have students think about what is in the atmosphere that leads to this issue. This discussion should be informed by Students then discuss the fact that some cities are worse off than others in terms of how polluted the atmosphere is above their city.

Teacher then assigns students to groups of three or four. Students do a Google image search of skylines of different cities around the world and, from this search, pick three cities to focus on. Once they identify their three cities, groups analyze the image for clues as to how much the atmosphere obscures the sunlight for solar panels set up in that city.

Students then select and create a light block that correlates to that city's atmosphere. These blocks can be single layers or a combination of layers, depending on how the students analyze and interpret the city's skyline. While creating these blocks, students complete the Atmospheric Effect on Solar Panels worksheet.

The teacher facilitates a discussion between groups about what they are working on in the middle of the design/redesign process. What is working? What still needs to be done? What are you using to represent this part of the atmosphere? Why? How else could it be represented? Why? From this discussion, students will be able to glean more ideas for their block designs and become comfortable defending their design choices.

Students can use a multimeter to get the power output of the solar panels in the form of volts before and after the block is added. If students have never used a multimeter before, students will need to use the V 20 setting because this is the voltage setting that would work best for the multimeter's small output for this

project. From this setting, students can get data on how the amount of power decreases after the block is placed above the solar panel, which can lead to the amount of energy lost due to the atmospheric effects and pollution of cities: Energy Loss = V before block - V after block

Closure

Once students are done creating their blocks, groups will then create presentations to inform the rest of the groups about their blocks and their reasoning about why they created their block. The teacher can choose to have students present their presentations in whole group or small groups, depending on time available. At the end, the teacher should lead a discussion on what the students found about different atmosphere above cities and how their blocks accurately or did not accurately represent the atmosphere. Finally, students should analyze what they would do differently if given more time to continue the challenge, and how what they found out could help scientists investigate how pollution can lead to efficiency loss in solar panels.

ASSESSMENT

Pre-Assessment

- Students should be assessed on their knowledge based on the class discussion at the beginning of the lesson. Teachers could also give a quick ticket with simple questions, such as: How does the atmosphere affect the sunlight that reaches solar panels on the Earth's surface?

Formative Assessment

- The teacher should assess students through the design process. Students should be able to verbally explain what they are doing, why they are doing that, and how their actions are helping them achieve a better designed block. Teachers can ask formative assessment questions such as:
    - What is your reasoning for using this material?
    - How will this step help in your design of your block?
    - What do you still need to accomplish for your design?
    - Why did you not use _____ (specific material) for your design?
    - How can you make your design better adapted to your city?

Summative Assessment

- Students will fill out an exit ticket with three questions listed.
    1. How does your blocks represent their coordinating cities?
    2. What would you have done differently if you did this design challenge again?
    3. How can your block design help scientists understand how pollution can harm renewable energy?

OPTIONAL ASPECTS

Lesson Extension Activities

- Technology Extension - Since students compared the efficiency of the solar cell without the block and with the block, have students research online actual atmospheric data on pollution of different cities. Does the efficiency loss of their blocks accurately reflect the true efficiency lost as stated by the real-life data? The websites listed in the next section will be helpful in this extension.
- Literacy Extension - Compare the efficiencies of solar panels in space versus solar panels on Earth. Is there anything we can do to help boost the efficiencies of solar panels on earth in regards to the atmosphere? Create a letter or law proposal to help get your idea implemented. In the letter, the students should explain the problem to the lawmaker/policy leaders and then give steps to how the issue could be solved, complete with data as to why this problem should be solved.
- Design Extension - Teacher proposes the question "What do we do?" in regards to the feedback loop of more pollution, less efficiency of solar cells, less use of solar cells, which leads to more pollution. Have students create

possible solutions and on how to address this feedback loop.

- Critical Thinking Extension - Using the Amount of Sun graph links listed below, students can compare the amount of sunlight given over a number of hours for cities around the world. From this, the teacher can start a discussion on how this new data point could affect the efficiencies of their city solar cells even further. Another design extension would be to the use handmade lights above their blocks and cover part of the light to simulate the loss of light due to the city's potion on planet Earth. From there, students could compare their new efficiencies to their past efficiency without the portion of the light being blocked.

Technology Integration

Relevant websites:

- State listing for air pollution
- Worst polluted cities around the world
- CO_2 emissions per country (Pick a country and then scroll down to see data)
- Pollution data for specific cities (Type in a city on the left to see the data for each city)
- Map of air pollution
- Link to WHO data sheet (Click on Ambient (outdoor) air quality database link on the right of the page)
- Solar irradiance graph (scroll down for a graph on how much sun shines on Earth and in space)
- Amount of Sun graph (scroll down to see the graph titled World Solar Energy Map)
- Amount of Sun in the US graph

EDUCATIONAL STANDARDS

Next Generation Science Standards

- MS - ETS1 - 4 Develop a model to generate data from iterative testing a modification of a proposed object, tool or process such that an optimal design can be achieved
- MS - PS3 - 2 Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system
- MS - PS3 - 3 Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer
- MS - PS3 - 5 Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object

Science and Engineering Practices

- Developing and Using Models
- Constructing Explanations and Designing Solutions
- Engaging in Argument from Evidence

Cross-Cutting Concepts:

- Systems and System Models
- Energy and Matter
- Influence of Science, Engineering, and technology on Society and the Natural World

Arizona Science Standards

- S1C1PO3, S1C2PO1 / PO2 / PO3 / PO4 / PO5, S1C3PO2, S1C4PO3 / PO5, S2C2PO3, S3C2PO3, S4C3PO2, S5C3PO1

CONTRIBUTORS

Thank you to Josh Kennedy for help in creating this lesson, and Michelle Jordan for help in editing and extending this lesson. This instruction was developed as part of the Quantum Energy and Sustainable Solar Technologies (QESST) Research Experience for Teachers (RET) program. This material is based on work supported by the National Science Foundation (NSF) and the Department of Energy (DOE) under NSF CA No. EEC-1041895. Any opinions, findings, conclusions, or recommendations expressed in this material are those of the author(s) and do not necessarily reflect those of NSF or DOE.

Atmospheric Effects on Solar Panels Worksheet

Names: _____ Date: _____ Period: _____

How does the atmosphere affect the sunlight that reaches solar panels on the Earth's surface?

City research

City chosen (Include country)	Description of skyline on polluted days

Which city out of your chosen three has the worst pollution? How might that affect which materials you use to model the atmosphere of each city?

Block Design

Materials provided:

Materials to bring in (if any):

City One: _____

Real Life Items in the Air	Material(s) Used	Reasoning for Material Use	Voltage from Multimeter (use V20)

City Two: _____

Real Life Items in the Air	Material(s) Used	Reasoning for Material Use	Voltage from Multimeter (use V20)

City Three: _____

Real Life Items in the Air	Material(s) Used	Reasoning for Material Use	Voltage from Multimeter (use V20)

How can your block design help scientists understand how pollution can decrease the efficiency of renewable energy being used in real life cities?