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School Solar Analysis

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Lesson 4.2 Overview

Estimate Time:
90 minutes

Standards:
NGSS: HS-LS2-7, HS-ESS3-4, HS-ETS1-2, HS-PS3-3
CCSS.MATH: HSA.SSE.4
CCSS.ELA.LANGUAGE: L.9-10.1, L.11-12.1., L.9-10.6., L.11-12.6., SL.9-10.1.A., SL.9-10.1.C.
CTE: EEU 6.0, 6.3, 6.3, 6.6-6.13, 6.15, 6.16, 9.0, 9.2, 9.7 BC D11.0, D11.1, D11.2, D11.4, D11.6, D11.7, D11.9, D11.10, D11.12

Objectives: Students will be able to:
- Evaluate which solar array site will provide maximum power production
- Complete a solar installation project

Prep Time
- 1.5 hours for reviewing the lesson, assembling materials, and arranging the solar install field trip

Handouts
- 4.2.1 Rooftop Site Assessment & Solar Design
- 4.2.2 SketchUp 3D Modeling for Solar Design
- 4.2.3 SketchUp Cheat Sheet

Materials:
- Mini solar panel, multimeter, electrical leads, protracter
- SEI Energy Financial Calculator
- GRID Alternatives Safety PowerPoint Presentation

Lesson 4.2: Optimizing School Solar Performance through Design

A site assessment is a critical step in understanding a rooftop's potential to generate electricity from the sun. In this lesson, students will learn the fundamental steps for conducting a solar site assessment and designing a rooftop system. Students will continue their solar assessment and design project from Lesson 3 and either design the system for a sample California school's rooftop or their own school.

KEY WORDS

Azimuth: The angle, in a clockwise direction from north, that the solar modules face

Latitude: The distance, in degrees, north or south of the equator

Orientation: The placement and alignment of solar modules to face the sun. To capture the greatest amount of sunlight, the preferred orientation for solar is due south when array is located in the northern hemisphere

Shading: Shadows from manmade or natural features that block direct solar radiation from reaching the solar PV modules and diminish the production of electricity

Site: A location, such as a piece of land, parking lot, or a rooftop, where solar can be installed

Tilt: The angle of solar modules; optimal tilt, to capture the greatest amount of sunlight, is the same the latitude of the array location

Usable Area: The area of a roof that can support solar panels. This area takes into consideration the offset from the edge of the roof and any shading or mechanical systems that limit the area that can support productive PV panels

PREPARATION

- Review Rooftop Site Assessment and Solar Design Handout and complete the design and calculation steps to familiarize yourself with the procedure and tools.
- Print the following handouts:
  - Handout 4.2.1 Rooftop Site Assessment and Solar Design – 1 set per student
  - Handout 4.2.2 SketchUp 3D Modeling for Solar Design

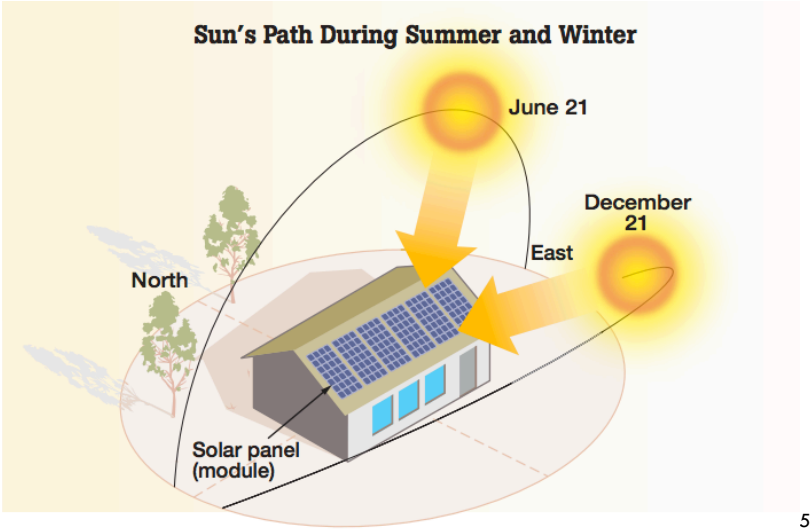
Recommended Lesson Breakdown

- Day 1: Solar Efficiency
  - Setting the Stage: Solar System Site Choice
- Day 2-3: Intro to SketchUp
  - Activity 1: Intro to SketchUp
- Day 4-7: Rooftop Site Assessment and Solar Design
  - Activity 3: Solar System Design

SETTING THE STAGE: SOLAR SYSTEM SITE CHOICE

- The choice of a proper **site** is one of the most important steps in solar system design. Even the most carefully sized solar electric system will not function optimally if it has not been installed in the proper location.
  - Most solar electric arrays are installed on rooftops. This can be an ideal location for a number of reasons. On a rooftop, the array is less likely to get damaged or shaded. The existing pitch of a roof can help angle the modules toward the sun. Rooftops offer space that would otherwise be unused, as opposed to developing an open field that could be used for another purpose such as promoting biodiversity, an athletic field, or an additional building at the school.
- There are several key considerations when looking for a proper roof solar system site.
  - **Roof area**: The optimal site for rooftop solar must be large enough to accommodate the solar array. Solar arrays on rooftops must be offset slightly from the edge of the roof due to safety requirements and any mechanical structures on the roof to avoid shading from rooftop structures. A rectangular roof with no structures is better than one with a varied shape or different angled roofs in one.
  - In the activity, students will determine the amount of usable area that a roof has. The **useable area** is the total roof area that can support solar panels. It takes into consideration the amount the solar panels need to be offset from the roof, as well as the amount of shading or mechanical structures on the roof that would limit the roof's capacity to support panels.

- Roof **Orientation**: South is the optimal orientation for solar panels, but you can still produce plenty of power from a solar array on a flat rooftop or a rooftop facing southwest.



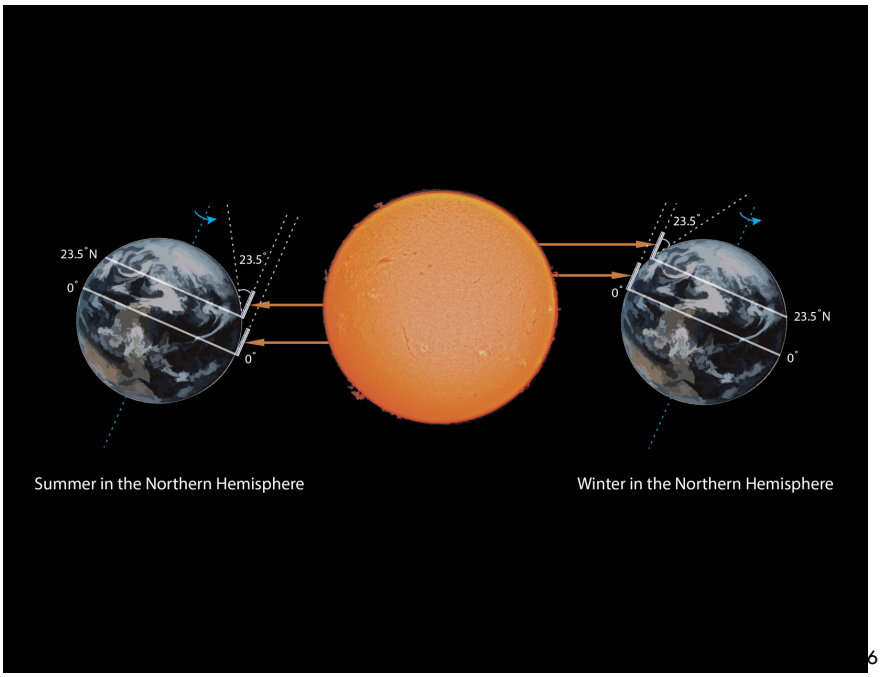
[5]

- **Shading**: Full or partial shading of the panels restricts the production of electricity. Even a small amount of shading can create a disproportionate reduction in electricity production. No shade between 9 AM and 3 PM is optimum. The location you choose should have little or no shading from trees, fixtures like chimneys or pipes, street poles, or other tall objects.

- **Tilt** (aka slope or pitch): A solar array should be angled so that it faces the sun for as much of the year as possible. The optimal tilt is equal to the location's **latitude** but the range between 15 degrees less than your latitude in the summer and 15 degrees more in the winter is sufficient, so if your roof is in this range, it's a pretty good location. Racking systems are used to support the modules and tilt them to the proper angle for roofs that are flat or very steep, but the more rack hardware you need, the higher the cost and possible weight impact of the system due to snow and wind.

The image below shows the approximate angle the panels should be tilted to in order to capture the most sunlight. Note, the Earth's axis is not perpendicular to the sun's rays which is why a range of tilts is acceptable.

[5] Source: http://www.nrel.gov/learning/pdfs/43844.pdf



[6]

- **Roof age:** Roof age is a key consideration for your site analysis. The system will function for 25 years or more, so if the roof is old, it may have to be replaced before installing solar. This will be a cost consideration for the district, but it is much more cost effective to replace the roof before installing solar than to remove the solar system in order to update the roof, and then reinstall the solar system. The good news is that a solar system will help to increase the useful life of the roof by protecting it from the elements.

➢ Some of these factors can be minimized by technology known as Maximum Power Point Tracking (MPPT) systems. MPPT systems sample the output of the PV cells and apply the proper resistance (load) to obtain maximum power production from solar cells for given environmental conditions, such as the level of illumination, temperature, or age of the cell.

[6] Source: Image developed by SEI volunteer Ruiheng Li.

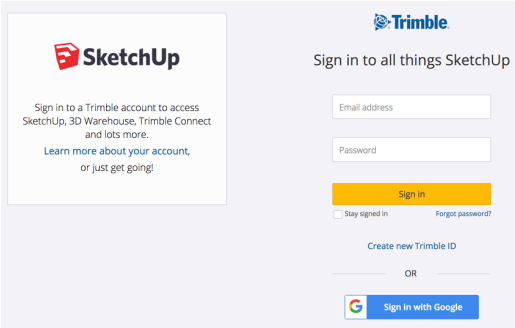
ACTIVITY 1: INTRO TO SKETCHUP

- **SketchUp** is a CAD (computer assisted design) software commonly used in engineering and building construction industries. A web app version of SketchUp Is available for free at app.sketchup.com.

Preparation

- Before leading students through this activity, it's a good idea to review and complete the steps below on your own. Once you're ready to start the activity, below are some suggested guidelines:
  - Provide students with laptops or access to a desktop computer and make sure they are all connected to the internet. Set up your own computer to display on the projector and ensure all students can clearly see the projector screen. Give each student a copy of SketchUp Cheat Sheet Handout.
  - If possible, have students work in pairs so they can help each other if needed.
  - Explain to students they should be watching you as you will read each step out loud and complete the action on your own computer. Next, they will have the chance to repeat the step on their own computer. Not all steps require students to do something on their own.
  - This an opportunity to 'model' steps that students will take in their use of the Sketch Up tool as part of this assignment while the students are taking notes and you as the instructor have their full attention. Teaching computer aided drafting allows an opportunity for teachers to 'chunk' a number of steps, break from instruction and modeling, release students to do these steps, return for questions and clarity, and then begin modeling the next steps, release, etc.
  - Read each step out loud to give students a preview of what they are about to do. Next, give students some time to complete the action before moving on the next step.

Getting started with SketchUp



1. Open a web browser (e.g., Chrome; note that some browsers such as Safari may not be supported), go to app.sketchup.com, and sign up for an account. (Note: If your school uses G Suite for Education, direct students to sign up with their Google account by clicking "Sign in with Google".)
2. You have the option of completing a brief tour of the application interface. Click on "Start tour". (Note: If you want to access the tour later, click on the **Help** (?) button in the Status bar and select "Launch welcome tour".)

HANDOUT: SITE ASSESSMENT AND SOLAR DESIGN

Name: _____ Date: _____ Period: ____

In this worksheet, you will continue the assessment of your school to determine the system location, and size. The handout will guide you through the steps described below, and the chart below maps the process.

- You have already determined the **required system size** by examining your school's utility bills and taking into account derate factors.
- In this activity, you will select a roof and determine the **maximum system size** based on the area of the roof and considering obstructions, shading, tilt, and orientation.
- Once you have determined both the required system size and the maximum system size, you can compare the two numbers and determine if you have a surplus or compensating measures are needed. If more areas suitable for solar (other rooftops, parking lots, etc.) are available, you can repeat the solar design process steps to supplement production.

Recall the DC system size requirement determined in Sizing a Solar Electric System.

34. In the Sizing a Solar Electric System Handout, you determined the $kW_{size\ needed}$ of a system needed for a system to produce 80% of electricity consumed at the school, including derate factors.

    _____$kW_{size\ needed}$ determined in Sizing a Solar Electric System

Note that the $kW_{size\ needed}$ determined does not include any roof considerations. Panel orientation and tilt must be considered when determining how large the system must be at the school, as well as rooftop obstructions and shading. In the remainder of this handout, you will take all of these factors into account.

Basic facts about your roof's solar potential.

35. Starting with this step of your analysis, you will use computer-based tools to analyze your solar installation site. These tools include computer assisted design (CAD) and geographic information systems (GIS).

    a. **Project Sunroof** – a Google application to help estimate the solar potential of different rooftops in cities around the US.

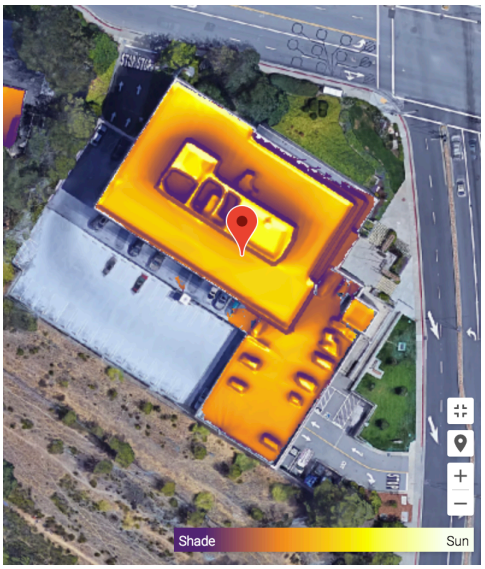
    b. **Google Maps** – satellite imagery will help you assess the rooftop targeted for solar installation without having to do in-person inspection and measurements.

    c. **SketchUp** – a CAD tool (available as a web app) commonly used in engineering and building construction industries that will help you estimate available space and create a layout design for your system.

36. In the northern hemisphere, south is the optimal orientation for a solar array but you can still produce plenty of power on a pitched rooftop facing southwest or southeast. When selecting a rooftop, consider any shading or rooftop structures that may affect the output

of your school's system. Remember the panels need to be offset from the edge of a roof and any mechanical equipment on the roof.

37. **Project Sunroof** is a web application developed by Google and capable of estimating the solar potential of rooftops in many cities around the US.



   a. Go to www.google.com/sunroof and enter your school's address in the search box labelled "Enter your home address". Next, click on Check My Roof to see some key statistics about your location.

   b. The solar potential for your roof is shown on a color scale (from "Sun" to "Shade", see image). This information is helpful when determining which areas of the roof experience shading throughout the day from nearby buildings, trees, or rooftop structures (such as AC units). What initial observations do you have about the roof selection from Project Sunroof? (i.e. Is the entire roof selected?)

_____

_____

_____

_____

   c. Other parameters such as hours of usable sunlight based on day to day analysis of weather patterns and estimated surface area are available on the website. Keep in mind that these are estimates that do not consider specific site constraints.

   d. Record the information in the table below:

Type of roof and orientation	☐ Flat ☐ Pitched If pitched, what is the roof orientation? ☐E ☐SE ☐S ☐SW ☐W
Average hours of usable sunlight	a. Per year: _____ (from Project Sunroof) b. Per day: _____ (divide number above by 365)