SEI STRATEGIC ENERGY INNOVATIONS

Grade 9-12

Version 7

August 2019

Solar Certificate

Design, size, and site a school solar system; implement school energy conservation measures; install a residential solar system

Table of Contents

Curriculum Matrix: Solar Certificate

26-28 hours of coursework and a 1-2 day solar installation

Module		Lesson		Estimated Time	Description
1	Sustainability, Energy, & Climate	1.1	Sustainability: Problems and Opportunities	45 minutes	In this module, students are introduced to the Solar Installation Project and Certificate and gain a basic understanding of sustainability issues; climate impacts; fundamentals of energy, energy sources, energy-efficiency, and renewables; and economic and environmental justice. Students will come up with 30-second messages on climate change, give short class presentations analyzing either a cause, consequence or opportunity of climate change, and research the environmental justice issues related to energy.
		1.2	Climate Change	225 minutes	
2	Energy & Solar Science	2.1	Energy and Power	60 minutes	Students are introduced to the fundamentals of electricity: energy, power, current, voltage, and resistance. Students will learn the terminology and symbols relating to electricity and create and test their own electrical circuits. Students will build mini-generators to produce electric current, complete an activity where they diagram and make an electrical circuit, analyze their local fuel mix and analyze energy storage, critical for the solar industry.
		2.2	Electrical Circuits	90-135 minutes	
		2.3	Electricity Grid	135 minutes	
		2.4	Energy Storage	90-135 minutes	
3	Energy Efficiency & Conservation	3.1	Auditing Plug Loads	45 minutes	Students learn the difference between energy efficiency and energy conservation, and identify opportunities for both in their homes and school. Students will complete a walk-through energy audit of their school and write an energy audit report. Then, they will create and implement an Action Plan for promoting energy conservation at their school.
		3.2	Auditing Lighting	90 minutes	
		3.3	Conservation Action Planning	135 minutes	
4	Fundamentals of Solar	4.1	Solar Science and Industry	90 minutes	This module is designed to develop students' understanding of solar power. Solar power, a renewable resource, uses energy from the sun to produce electricity. Peak solar production closely mimics peak energy use, so solar power is a valuable tool for reducing peak power demand. Furthermore, students learn the components of a solar electric system and variables that impact solar power production.
		4.2	Solar Design	90 minutes	
5	Solar Systems and Installation	5.1	Solar Site Assessment	315 minutes	Solar system design is a critical step in understanding a rooftop's potential to generate electricity from the sun. Students will model the

		5.2	Energy Project Financial Analysis	90-180 minutes	components of a solar electric system and complete a design activity for a solar PV system, maximizing solar production at their school. Students will conduct a financial analysis of their solar systems. Using SketchUp, handouts, and the financial analysis calculator, students will be able to produce a model of a solar installation and justify the economic, environmental, and equity impacts of installation to an audience. Finally, students will complete a hand on residential solar installation project, which will provide students with transferable job skills and experience.
		5.3	Final Solar Design Project	45-90 minutes	
		5.4	Grid Installation	1-2 full day(s) for solar install project	
6	Green Career Pathways	6.1	Energy Careers*	90 minutes	Students explore the market sectors and job opportunities available in the green economy after obtaining marketable skills and knowledge by completing this curriculum. Students will complete a self-assessment to aid in identifying their career interests, will develop job search skills and materials, and will then, ideally, speak with professionals in the field.

*There is an optional extension to the Green Careers lesson in which students identify and seek a green job internship. This is an ongoing 5-month project.

Lesson 4.2: Solar Design

This lesson introduces students to the components of a solar electric system and leads students to explore variables that impact solar power production.

Lesson Overview

Estimate Time:
90 minutes (two 45 minute periods)

Standards:
NGSS: HS-EST1-1, HS-PS3-1, HS-PS3-5
CTE Standards: EEU A1.4, B1.1, B6.0, B7.0

Objectives: Students will be able to:

- Explain how solar electricity works
- Use a multimeter to measure electricity output from solar panels
- Describe the benefits of solar electric energy and the estimated industry growth of the solar industry

Prep Time:
30 minutes – 1 hour

Handouts

- 4.2.1 Solar System Components
- 4.2.2 Maximizing Solar Power Production

Materials:

- Pipe Cleaners
- Solar Toolkit: Mini solar panel, multimeter, electrical leads, protractor
- Compass (available on smart phones)

KEY WORDS

Combiner Box: A device that combines the output of all of the modules in a PV array for connection to the inverter

DC Disconnect: A safety feature that allows the DC current from the modules to be interrupted before it reaches the inverter

Inverter: An electronic device that converts direct current (DC) from solar panels into alternating current (AC), the form of current used in homes and businesses that are connected to a utility grid

AC Disconnect: A safety feature that allows the system to be disconnected from the grid

Electrical Panel: Combines power coming from the solar array with power coming from the utility grid

Racking: The mounting system that attaches the solar array to the roof

Utility Grid: The infrastructure facilitating the transmission and distribution of power from power plants and solar producers to the end user

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

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

PREPARATION

- Review lesson and materials on solar science. Access to Internet and a projector are necessary to display PowerPoint presentation and short videos.
- Activity 1 requires one solar toolkit for each group of 3-4 students, or can be done as a class demo to reduce costs.
- Print the Solar Research Project Handout – one per student

Recommended Daily Breakdown

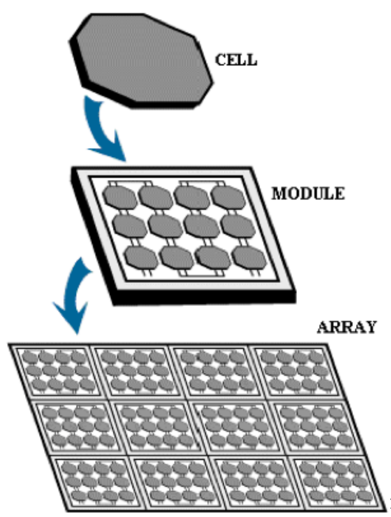
- Day 1: Solar Design
  - Setting the Stage: Solar Design
  - Activity 1: Solar System Components
- Day 2: Maximizing Solar Power Production
  - Activity 2: Maximizing Solar Power Production

SETTING THE STAGE: SOLAR DESIGN

- Solar power systems are comprised of many components beyond the photovoltaic cells and panels themselves. There are a number of steps required before power produced by solar systems can be used on site (in the rare case of an off-grid system) or flow into the grid.

Mechanical Mounting Structure

Recall, solar modules are a collection of solar cells wired together to form an array.



[23] Image Source: http://science.nasa.gov/science-news/science-at-nasa/2002/solarcells/

- These solar modules are directly connected to a **racking** structure, which secures the system to a roof, the ground, or a shade structure. A weather station is often mounted near the panels to monitor wind speed, direction, and temperature. It collects data and sends it back to a monitoring system.

Electrical Structure (DC side)

- Photovoltaic cells produce electricity in direct current (DC). The DC current generated by the modules runs into a **combiner box** that combines the power from all the modules.

- The DC current then runs through a **DC disconnect,** an important safety feature that disconnects the output of the modules from the rest of the system. This is needed for system maintenance or troubleshooting.

- From the DC disconnect, the DC current runs through a **system inverter,** which changes the current from DC to AC.

Electrical Structure (AC side)

- From the system inverter, the AC current runs through an **AC disconnect,** used if the system needs to be disconnected from the grid. This is another safety feature required by utilities.

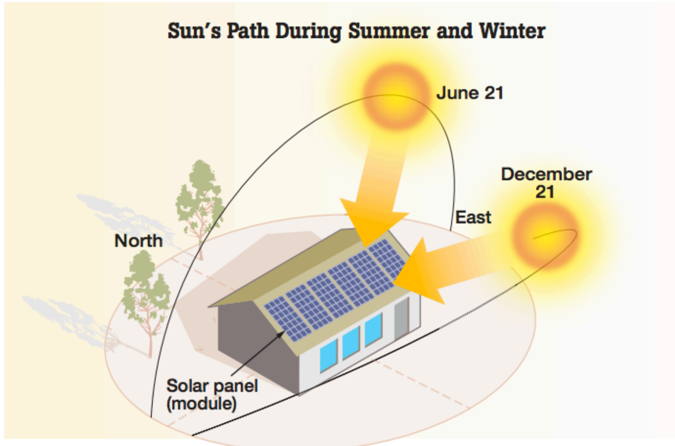
- The current then moves to an **electrical panel**. The electrical panel combines power coming from the solar array with power coming from the **utility grid,** which travels through the utility meter. The electricity coming from the electrical panel is then used to power appliances.

Solar System Site Choice

- There are several key considerations when designing a solar system.

  - **Orientation**: South is the optimal orientation for solar panels, but you can still produce plenty of power from a panel facing west or east.

  - **Tilt**: A solar panel should be angled so that it faces the sun. 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.



[24]

- **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.

- When choosing how to orient the solar phone charger, the panel should be perpendicular to the sun's rays as often as possible. Remember, any shadows cast on the panel will result in a decrease in production.

ACTIVITY 1: SOLAR SYSTEM COMPONENTS

- In this exercise students will design a grid-tied photovoltaic system with a system inverter. A solar array contains many components. Students will work in groups of approximately 4 students to design a solar PV system with all the components using the solar system components cards from their handout. The answer key showing the correct layout for the system is at the end of this section.
- Groups will need space on a large table or the floor to layout their systems.
- We suggest giving this activity to students before describing the components and design of a solar photovoltaic system, allowing them to apply critical thinking skills to hypothesize about the function of system components and how they are arranged to produce useable AC electricity. Then allow them to modify their design once the functions of the components, provided in Setting the Stage, are described.
- Give each student group one set of all 12 cards in the Solar System Design Cards Handout and pipe cleaners of two different colors. Have students arrange the cards to mimic the way they think a system is structured. Explain that the two different colors of pipe cleaners represent the two different types of current that will flow through their wires (represented by

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

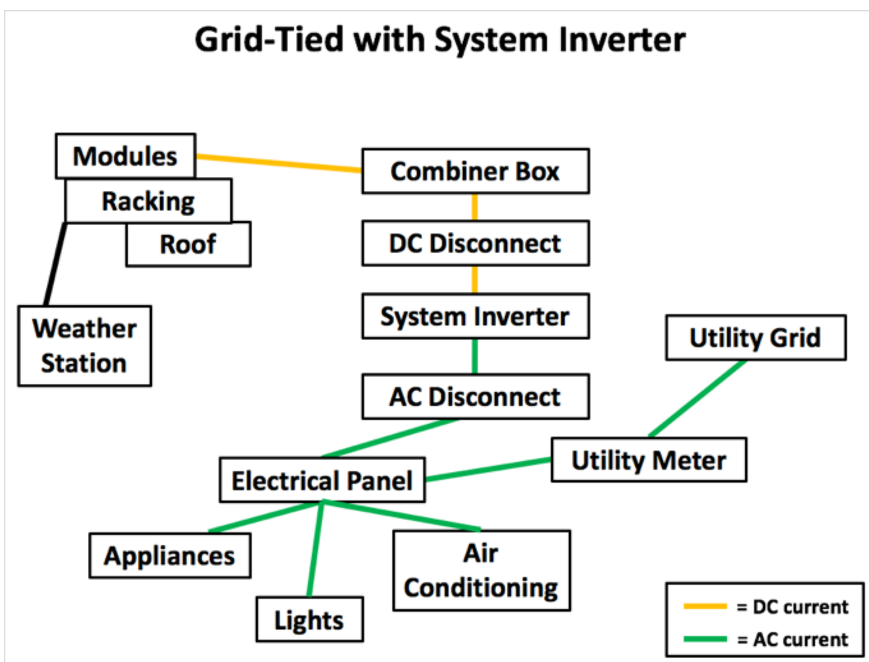
the pipe cleaners): DC and AC. Instruct students to connect the different electrical components of the system with the pipe cleaner wires depending on the type of current at each stage.

- Optional: Provide Internet access to allow members of the group to quickly research the function of different components if they get stuck on a system design question.
- Optional: Ask students questions to help them arrange the components.
  - Which components have they seen before? *(Students may recognize the electrical panel or the utility meter from their own homes. Ask them to think about where those components are located in their house.)*
  - Based on the name of the components, what do students think the components do? *(Think about the word inverter. What would this component be inverting? Think about the combiner box component. What would it combine?)*

➢ Once student groups have had the opportunity to layout their systems, have half of the groups travel around the room at a time for short peer presentations and observations on designs and why they arranged components as they did.

➢ When student presentations are complete, fill in knowledge of system design and component function as needed.

➢ The correct layout of a system will look similar to this:



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[25] Source: Pete Shoemaker PG&E

ACTIVITY 2: MAXIMIZING SOLAR POWER PRODUCTION

- This activity can be done in small groups or by individual students. The activity must be done outside, with sunlight as the power source, so that students can measure the impact of different factors on the panel output.
  - *You may want to save this activity to be done by students on the day of the GRID installation.* There can be a fair amount of down time between parts of the installation project, as different teams sometimes need to wait for others to finish before moving on.
- Provide each group or student with a copy of the Maximizing Solar Power Production Handout.
- With the handout as a guide, students will have the opportunity to investigate different factors to determine how to design their solar system in a way that maximizes power production.
  - This handout can be extended by asking students to graph their findings.
- Discussion
  - Why do you measure higher current when the panel is tilted more towards the sun?
  - Why do you measure higher voltage when the panel is tilted more towards the sun?