Energize Schools

Distance Curriculum Preview

This distance learning curriculum preview was developed by Strategic Energy Innovations (SEI) and includes one activity from the Transportation Analyst 101, Solar Design 101, and Energy Consulting 101 curriculum.

The following additional resources are available for request through this google form, our Energize Schools distance learning website, or via an email to energizeschools@seiinc.org:

Access to the full SEI curriculum library

Waste Analysis | Water Conservation | Transportation Analyst | Solar Design | Energy Consulting

An editable version of this curriculum and/or answer keys

Remote curriculum implementation support from an SEI expert

Access Green Careers Conference webinars and recordings of career chats with sustainability professionals. To register and tune in live, go to our website here or request the presentation recordings here.

Join the Earth Day Campaign Competition to help students connect to their peers. Students will learn about climate change and sustainability, receive resources to create a campaign, and submit their work for prizes! Register here.

If you have interested colleagues, please direct them to our distance learning web page to request resources or have them reach out to energizeschools@seiinc.org.

Solar Design 101

Curriculum Preview

Request full curriculum here

If you have interested colleagues, please direct them to our distance learning web page to request resources or have them reach out to energizeschools@seiinc.org.

Reader: Planning and Sizing a Solar System

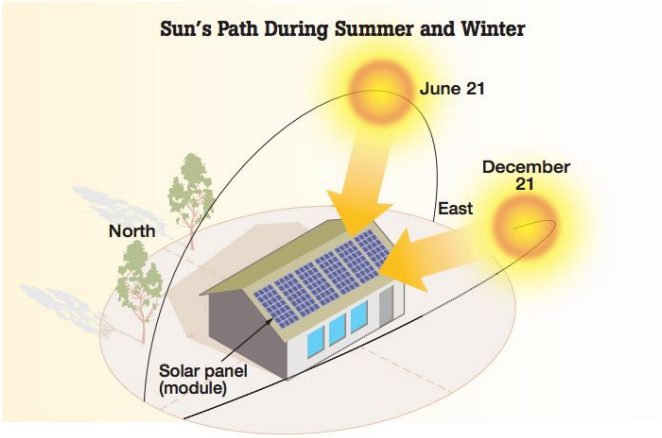
Solar System Site Choice

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. 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.

The **usable 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 in the Northern hemisphere, but you can still produce plenty of power from a solar array on a flat rooftop or a rooftop facing southwest.



[1]

Roof 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.

Roof 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

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

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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. Mounting 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.

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, 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.

Solar and Direct Current (DC) vs. Alternating Current (AC)

Watch Basic Benefits of Going Solar by SoCal Edison. Observe that Solar Panels produce DC current while appliances in your home use AC current. This will become important to remember when calculating the size of a solar system needed for a home.

Derate Factors

One hundred percent of electricity produced by a solar panel does not make it into the home to be used. To calculate the loss of electricity from the panels to actual in-home use, a **derate factor** is used to account for inefficiencies and power losses that occur between the electricity production at a solar panel and the delivery of electricity to the home (or customer).

- Production tolerance: Panel performance is assessed using standard tests in a laboratory, but actual performance of panels once installed in the real world will differ
- Higher temperature: Panels are less efficient at producing electricity when the temperature is higher
- Dirt and dust: The collection of dirt and dust on the modules reduces the amount of light that reaches the PV cells
- Module mismatch: All panels are slightly different, and since the panels are strung together sometimes power is lost as it moves through the array
- Line loss: As the current moves through the wire, there are losses (in the form of heat) due to the resistance of the wire and other electrical connections in the system. **Insolation**

In addition to derate factors, the amount of energy a solar system can generate depends on the amount of sunlight the region receives.

- The amount of solar energy reaching your school is affected by the season, the time of day, the climate, and air pollution.

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Insolation, incident solar radiation, is the amount of solar radiation striking a given area over time, measured in kilowatt-hours per square meter (kWh/m^2). The map below shows insolation in different parts of the United States. You can see that insolation in the southwest is higher than in the northeast.

Insolation can be used to determine the **peak sun hours** per day (PSH/D). A peak sun hour is the average number of hours per day of "full sun" at a given location. One peak sun hour is equivalent to 1,000 Watts of solar power striking one square meter of surface area for one hour. Areas with higher insolation have higher peak sun hours per day.

Buildings with solar systems often produce more power than they use during the day and rely on power from the grid during the night. Since the power they sell back to the grid during the day is more valuable than the power they get from the grid at night, the solar system can produce less kilowatt hours of electricity than the home uses, but still offset all of the electricity generation costs for the site.

- When designing a solar system for a home, the goal is to balance the cost of the electricity, not the amount of electricity used.
- We often size solar PV systems to produce about 80% of their annual electricity usage because:
    - Homes can offset all of their electricity costs with a system smaller than their usage because the value of electricity is greater during times of solar production, (especially during the summer when usage in households is low).
    - Utilities are moving to "time of use" rates, which means customers pay more for electricity used during times of peak demand, like during the day and in the summer when air conditioning is in demand.
    - The home may become more energy efficient (use less energy) in the future.

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Assignment: Planning and Sizing a Solar System

In the following questions you will work to describe the advantages and disadvantages of installing a solar array in the Mojave desert in Southern California.

1. What would be the best orientation for a solar array in the Mojave desert? Why?

2. How does the path of the sun affect the optimal tilt and orientation of the solar modules in the northern hemisphere?

3. Where is the Mojave desert located? Can you find it on a map?

4. List the 5 derate factors. Circle the two derate factors that change the most based on panel location.

    a. What is the temperature like in the Mojave desert? Considering what you know about derate factors, is temperature an advantage or disadvantage to installing solar here?

    b. Do you think it would be easy or challenging to keep solar panels clean in the Mojave desert? Why does it matter if the panels are clean or not?

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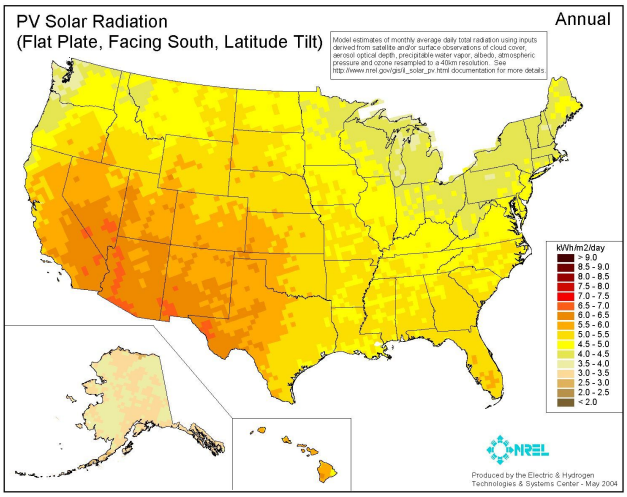
5. How many peak sun hours per day does the mojave desert get?
    a. Using the map below and your knowledge about where the mojave desert is what is your estimate for psh/day?



[1]

    b. Looking up peak sun hours using the Solar Insolation - Sun Hours Per Day website what is your estimate for psh/day? (note: Inyokern, CA is the closest city to the Mojave desert)

    c. Based on your research, describe why the peak sun hours in the Mojave desert is an advantage or disadvantage to installing a solar array?

6. Given your background research on the impacts of derate factors and psh/day in the, would you install a solar array in the Mojave desert? Why or why not?

[1] Source: Solar Resource Data, Tools, and Maps | Geospatial Data Science

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Part 2: Sizing a Solar Electric System

Determine the size of a grid-connected solar electric system for powering *80%* of the electricity of your home or an average home in California.

The average electricity use of a home in the United States is **903 kWh a month.**[2]

Step 1. Calculate average annual and daily energy use: Use the average above for calculations.

Tip: To fill in the calculations below, replace the lines with numbers and calculation results.

Annual Energy Consumption:

$$_____\ Average\ \frac{kWh}{month} \times \frac{12\ months}{year} = _____\ \frac{kWh}{year}$$

Daily Energy Consumption:

$$_____\ \frac{kWh}{year} \times \frac{year}{365\ days} = _____\ \frac{kWh}{day}$$

Step 2. Determine the amount of greenhouse gases emitted to power your home. Use the national greenhouse gas emission factor or research your local utility's emissions factor (National Average: 1.2 lbs CO_{2e}/kWh)

Annual Greenhouse Gas Emissions:

$$_____\ \frac{kWh}{year} \times _____\ \frac{lbs\ CO_{2e}}{kWh} = _____\ \frac{lbs\ CO_{2e}}{year}$$

Step 3. Find your location's average peak sun hours per day (PSH/D) An insolation map shows an average of how much sun per day reaches different geographic locations. The insolation at a given area can be used to determine the peak sun hours per day. The average for California is 5 peak sun hours a day. One peak sun hour is equivalent to 1,000 Watts of solar energy striking one square meter of surface area (in this case, a south facing solar collector sloped at 25° - 55° from the horizontal with no shading) for one hour. You can look at solar resource maps online, or

[2] Source: How much electricity does an American home use? - FAQ - US Energy Information Administration

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use 5 peak sun hours per day (PSH/D) for this activity. A map can be found at Solar Insolation - Sun Hours Per Day.

$\frac{PSH}{D} = _____5_____$
$\frac{D}{PSH} = _____$

Step 4. Calculate the system size (AC watts) to provide 80% of the home's electricity. We only want to recommend a system size that will produce 80% of the home's annual electricity usage because:

1.) The home may become more energy efficient in the future.

2.) Homes are compensated at a lower rate for the electricity they over produce. At the end of the year the utility company will calculate whether the home has produced a higher monetary value of electricity (rather than kilowatt-hours) than it has used, but if the home produces extra over the year, it is compensated at a low rate – approximately $0.03 per kWh, so it is not cost effective to recommend a system that is larger than needed to meet the home 's needs.

Find 80% of the home's daily electricity use:

$_____ \frac{kWh}{day} \times 80\% = _____ Target \frac{kWh}{day}$

Divide the daily average electricity use by average sun hours per day:

$_____ Target \frac{kWh}{day} \div _____ \frac{PSH}{D} = _____ kW_{production}(AC)$

Step 5. Determine the DC system size. The DC system size is found by taking into account all of the factors that can reduce the total output of the system. There are a number of parts that make up a solar electric system, and as power moves through that system some of the power is lost – no part of a solar electric system is 100% efficient. There are many factors that lead to a system not producing to its maximum potential. These 'derate' factors are included in the table below:

Derate Factor		Loss	Derate
Production Tolerance	Solar modules are marketed according to their performance in a laboratory, not in the real world	7%	.93
Higher Temperatures	Solar modules produce less power when they get hot	9%	.91

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Dirt and Dust	Dirt and dust on the modules reduce power output	2%	.98
Module Mismatch	Some power is lost as it transfers from one solar module to another	2%	.98
Line Loss	Some power is lost through wires and wire connections	3%	.97
Inverter Loss	The inverter is not 100% efficient in 'inverting' the incoming DC power into useable AC power	4%	.96
Total Derate Factor for a PV system = 0.93 x 0.91 x 0.98 x 0.98 x 0.97 x 0.96 = **0.76**			

The PV system should be designed such that enough DC power is produced that even with the derate factors the system produces the AC power calculated in Step 3. Calculate the system DC system size by dividing the kW (AC) by the derate factor calculated above.

$$\frac{kW\ (AC)}{0.76} = _____\ kW_{size\ needed}\ (DC)$$

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