Accessing Solar Energy Data for Classroom Use

Instructional Guide and Lesson Plan Ideas

Overview

On the Solar 4R Schools website, teachers and students can access live solar energy data through the "Energy Exploration Center" where various data sets from some of our solar projects are maintained. Teachers, students, funding partners, and community members can use this tool to view graphical displays of variables such as energy, power, temperature, and irradiance for a determined time frame (within one year). These data are very useful classroom tools for engaging students in the projects right at their own school site or at locations around the country. The purpose of this handout is meant to provide instructions for accessing these data and offer ideas for how to best integrate this place-based piece into their curriculum.

Accessing Data

Selecting a Project

On www.Solar4RSchools.org, click the "Explore Data" tab and use the dropdown menu to select a project (Figure 1). Use Table 1 as a reference for tips on selecting a project and variables to explore.
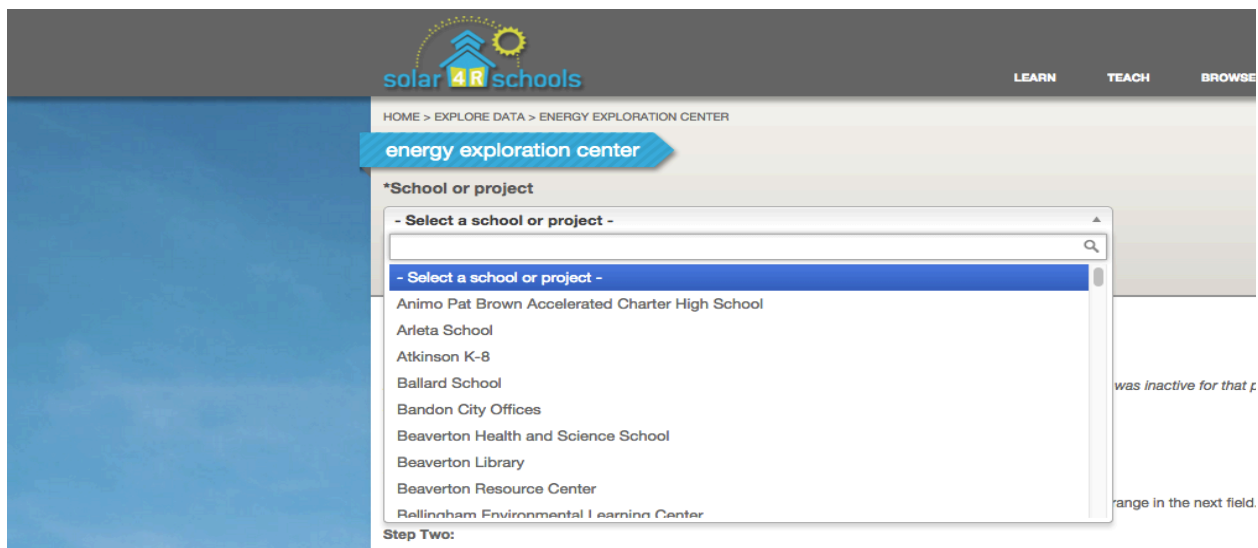

Figure 1. Accessing school data by site, www.solar4Rschools.org/explore-data.

Table 1. Options and tips for selecting a project to explore (www.solar4rschools.org/explore-data).

Options for Selecting Projects	Notes
A. Explore data for your specific project	Use the dropdown menu in "Explore Data" to select the project your school's project.
B. Explore data for recommended projects *Not sure where to start?*	Try some of these projects for extended data sets (you will still need to download data one year at a time) or across different geographies: - Lycee Francis, NY - Journey School, Jackson, WY (nice because this system includes wind speed) - Camino Nuevo Charter School, CA - Eastern Washington University, WA (both fixed pole and tracker sites) - Ballard School, WA - Camino Nuevo Academy, CA - East Portland Community Center, OR - Orcas Island High School, WA
C. Explore data for any project in the Solar 4R Schools project list	You can simply click the "Browse Projects" tab and use the map to find a project in your desired region. To view data for this project, you will need to return to the "Explore Data" tab. *Note: not all projects in "Browse Projects" have data published to "Explore Data".*

Selecting Data Variables

Once you have selected your desired project, choose the desired variables you would like to see graphed (or downloaded, Figure 2). Bear in mind that not all schools will have the same variables monitored due to the wide variety of equipment installed at each site.
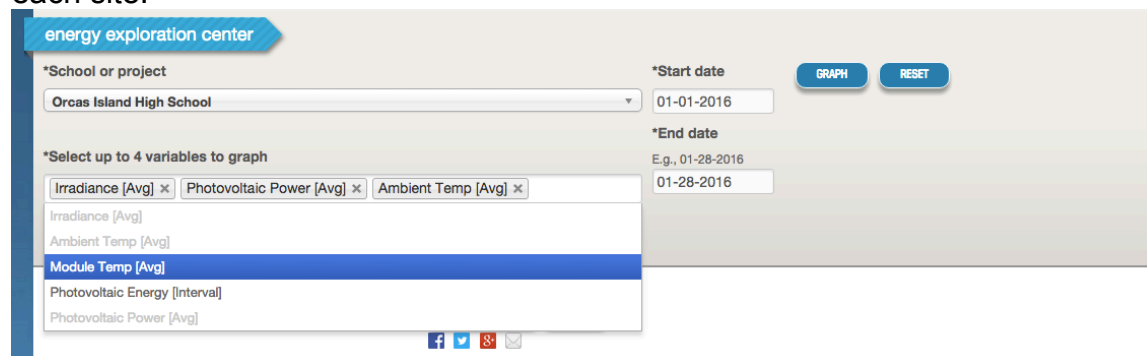

Figure 2. Example data variables and timeframe for project (Orcas Island High School) on www.solar4rschools.org/explore-data.

On some projects, pay close attention to the "[Avg]," "[Min]," and "[Max]" designations in order to determine whether it is the average, minimum, or maximum data point, respectively, for that variable. ***Generally, the "[Avg]" measurement will be the best option for classroom usage.*** You can select up to four variables to graph at one time. Use Table 2 as a guide to better understand the potential variables available for your project.

Table 2. Possible variables and descriptions to "Explore Data" on www.solar4rschools.org/explore-data. Note that not every project will include all data monitoring equipment, and therefore may not have all the variables listed below.

Data Variable	Notes
Ambient Temperature	temperature of the air (degrees Fahrenheit)
Module Temperature	temperature of the photovoltaic modules themselves (degrees Fahrenheit)
AC Voltage	voltage generated by the array after it has been converted from DC to AC by the inverter (Volts, V)
AC Current	current generated by the array after it has been converted from DC to AC by the inverter (Amps, or Amperes, A)
DC Voltage	voltage generated by the array before it has been converted to AC by the inverter (Volts)
DC Current	current generated by the array before it has been converted to AC by the inverter (Amps, or Amperes, A)
Photovoltaic Power	the rate at which solar energy is being transformed into electrical energy by the array (kilowatts, kW)
Photovoltaic Energy	measures the amount of energy generated over a specified time interval (kilowatt-hours, kWh)
Insolation	The amount of *energy* received in a given area, measured in kilowatt-hours per meter squared per day, $kWh/m^2/day$
Irradiance	measures the *power* in watts per meter squared (W/m^2) reaching the earth from the sun at a given time

Note: *Again, not all schools will have access to the complete range of variables. If you are hoping to undergo one of the below classroom activities and are missing a variable,*

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try accessing data for a school site close by that does have access. Refer to the sites listed above under "Selecting a Project" that have a wide range of variables.

Graphing Tips

- Make sure that you understand that data will be reported over different intervals depending on the date range that you choose. For instance, if graphing Irradiance [Avg] and Power [Avg] over the course of 1 year, that data will be reported as a monthly average. If the date range selected is one month (Figure 3), the variables will be reported as a daily average. If you are unsure, download the data in CSV format and look at the time stamps – one month of data will have ~31 data points whereas one year of data will only have ~12.
- Sometimes data will not display or be very inaccurate if the technology used at the site is malfunctioning. Be sure to look closely at the numbers to determine if they make sense given your system's specs.
- If you suspect or know that your school's data is malfunctioning, select a new project site and view, graph, or download data from that site.
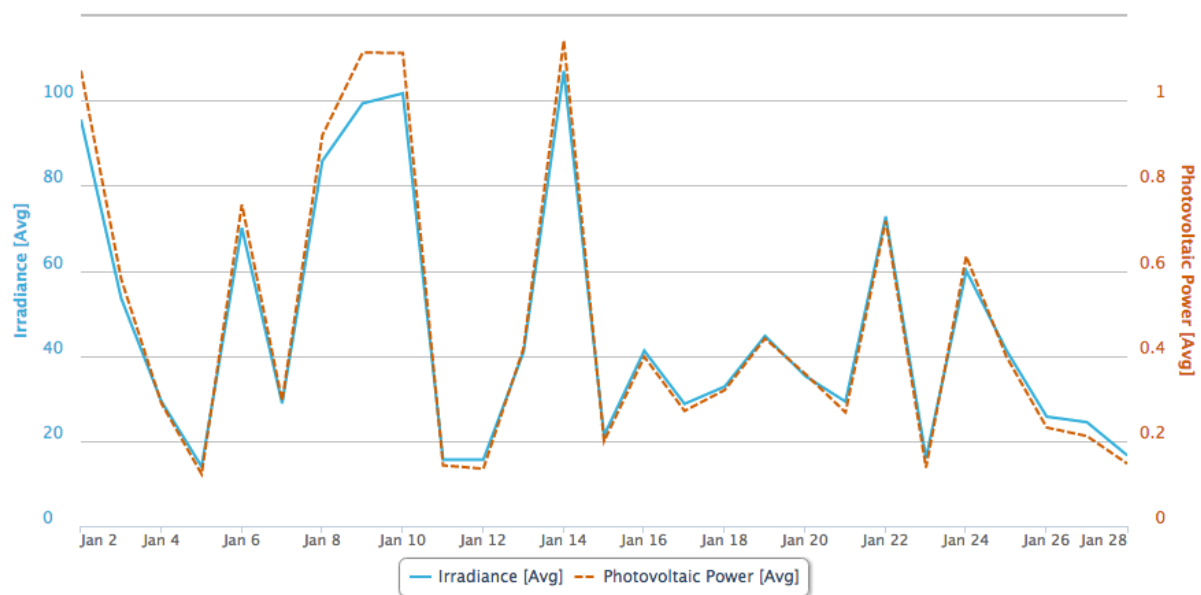

Figure 3. Example data graph: 1 month of average irradiance and power data. This graph shows a very close positive correlation between irradiance and power. However, data over the course of a year will not correlate so strongly. Because PV module efficiency varies with temperature, it is expected that these two variables will be negatively correlated at some points during the summer.

Ideas for Classroom Usage

There is no end to the ways you can utilize solar energy data for various lesson ideas. We noted a few ideas for incorporating solar energy data into classrooms below for the following topics:

- Seasonal Analysis

- Module Temperature and Efficiency
- Technology Efficiency

Seasonal Analysis

Using data from at least one year's worth of measurements, students analyze the effect of seasonality on their school's array. Have students make predictions before discussing weather patterns, checking after uploading the data sets to see if they are correct. Overlaying other variables such as irradiance (generally easier to analyze than insolation) and ambient temperature can aid in this discussion. Additionally, students can compare their school or region's data to that of another project in a totally different climate to see how seasons affect their power output. This is a great way to get students thinking about and discussing ideas such as intermittency in renewables, regional worth, and the value of diverse and flexible energy portfolios.
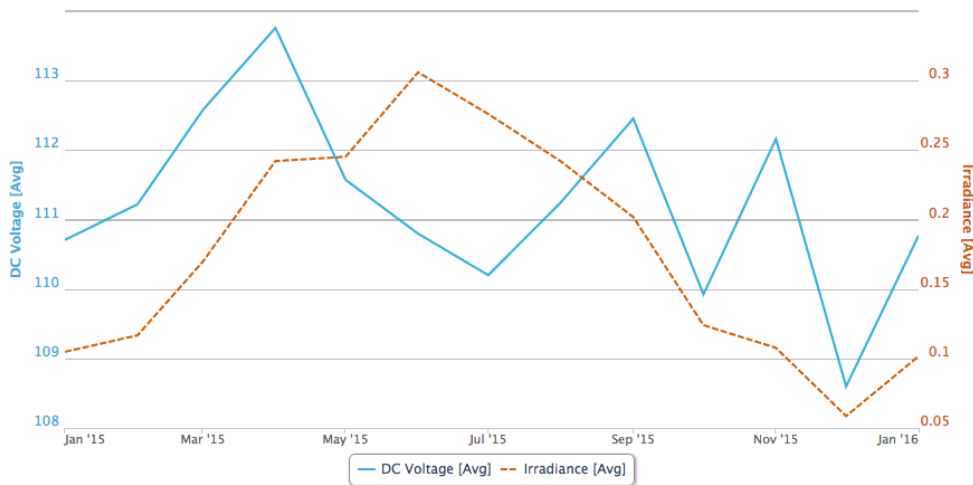

Figure 4. 1 year of DC Voltage and Irradiance data. Graphing these variables provides students a chance to look at general trends and perhaps anomalies in the data. Notice the drop in DC Voltage during the peak month for irradiance, which was July. This and other trends can be investigated using the activity below.

Module Temperature and Efficiency

If your school site has the "Module Temperature," comparing this variable with power/energy variables aids in the discussion of optimal conditions for solar power generation. Photovoltaics have a temperature threshold, which, after being passed, will decrease efficiency due to certain chemical characteristics. Generally, DC Voltage is the best indicator for getting this point across. Students can analyze trends in long-term data to investigate whether the hottest, sunniest days are truly the best for solar, which is often times the assumption. A great activity to pair this with would be an experiment using smaller, science-kit modules maintained at different temperatures connected to multimeters, taking controlled readings.
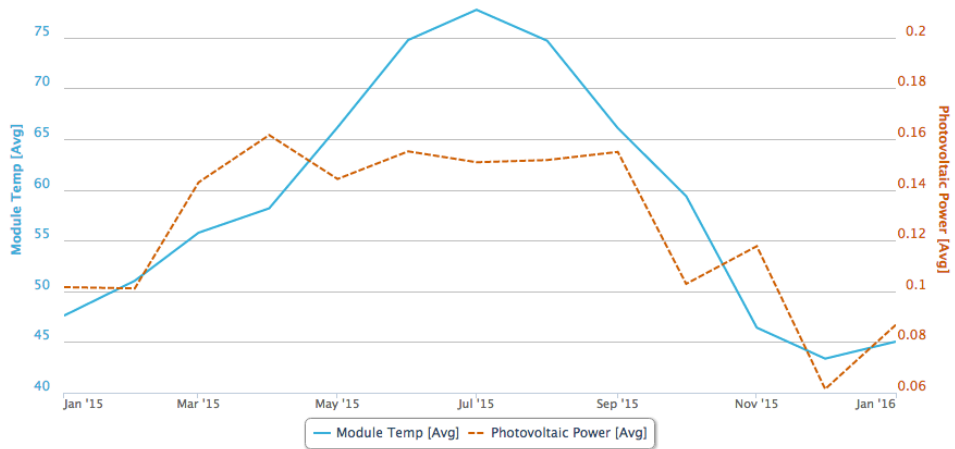
Figure 5. Module Temperature and Photovoltaic Power, 1 Year. This graph shows a slight correlation between module temperature and photovoltaic power (correlation doesn't equal causation!). Module efficiency will decrease as module temperature increases too high. This is viewable in the summer plateau and small dip in photovoltaic power.
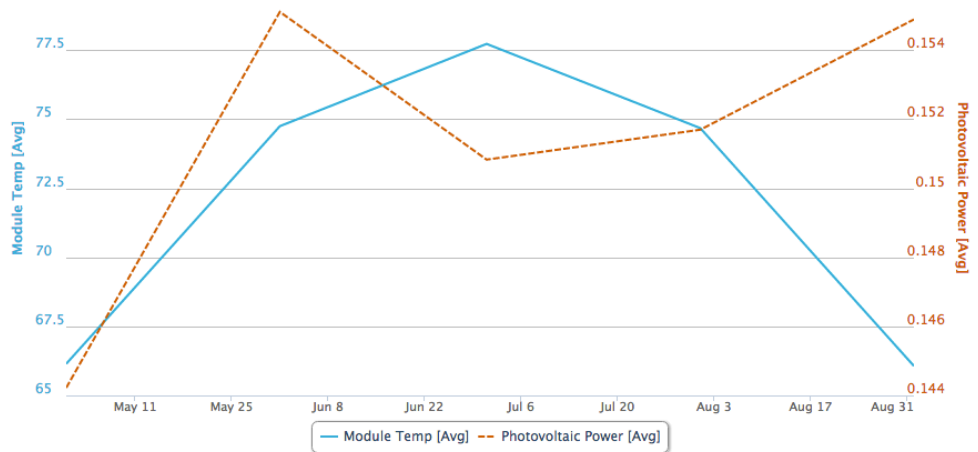

Figure 6. Module Temperature and Photovoltaic Power, Summer. Shortening the time scale of the above graph allows for a more detailed look at the peak module temperatures and decreasing photovoltaic power.
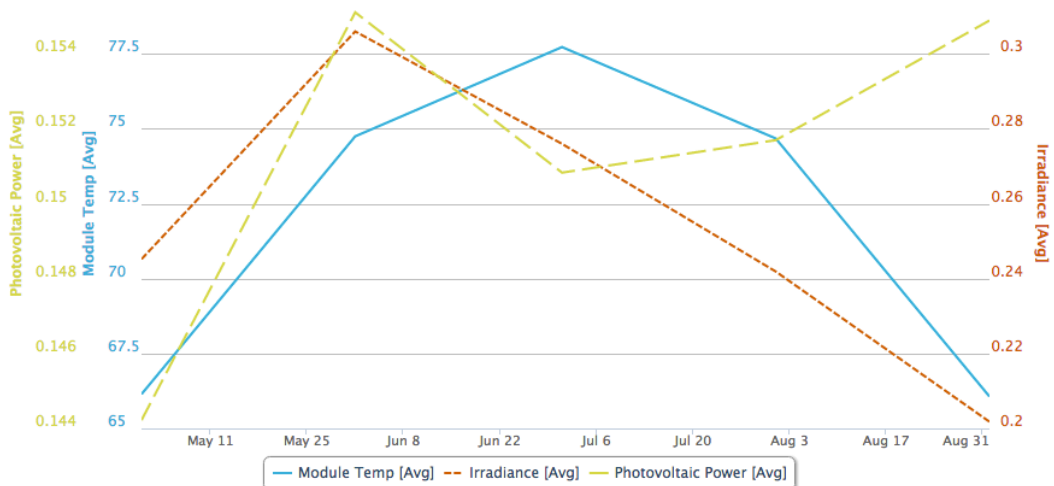

Figure 7. Module Temperature, Photovoltaic Power, and Irradiance, Summer.

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By adding a third variable, (irradiance, Figure 7), the story becomes more interesting. Note that at a point around July 6th, Photovoltaic Power continued to increase while irradiance decreased – it is plausible that the decrease in module temperature played a large part in this. However, when temperature begins to drop again during late July, power increases steadily despite a decreasing irradiance due to gain in efficiency from these temperature decreases. Downloading the data allows for statistical analysis of these variables, or for graphing them against each other.

Technology Efficiency

If insolation and/or irradiance are available data sets for your chosen school or project site, using power calculations can provide you with numbers necessary to calculate the efficiency of the modules on your schools roof (**Note**: Be sure to understand that the power from your module must be calculated for 1m^2 to make an accurate comparison to irradiance/insolation, meaning you must know the size of the modules on your school to convert their output down to what only 1m^2 would generate – this information can be found in the spec sheets for your array).

Students can additionally gauge the efficiency at which the inverter converts power. For this, they will need to calculate AC power and divide it by DC power, the formula for this efficiency being:

$$(\text{AC Voltage} \times \text{AC Current}) / (\text{DC Voltage} \times \text{DC Current}) \times 100 = \% \text{ efficiency}$$

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