

Solar Learning Lab™

User's Guide



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INTRODUCTION

The Heliotronics Solar Learning Lab™ allows you to access real-time data from your photovoltaic (PV) system and weather instrumentation. Using the SunViewer software, users can explore how a PV system works, view real-time data displays and access meteorological data.

This manual is written specifically for teachers and museum curators and other educators who want to use the Heliotronics Solar Learning Lab™ as an educational tool. The manual includes background information on PV, an explanation of the data acquisition system (DAS) components, a guide to using the DAS for educational purposes, and a list of activities. For instructions on installing the software, refer to the Heliotronics Software Manual provided with your system.

WHY SOLAR ENERGY?

Solar Energy and other forms of renewable energy provide electricity with minimal environmental degradation. Electricity generated directly from sunlight is generally referred to as Photovoltaic or PV. Energy has substantial impacts on:

- The economy
- The environment
- Health
- National Security
- Geopolitics

More and more, students and teachers are aware of the relevance of energy to so many aspects of their lives. Further they are sensing the urgency of the need for change.

UNDERSTANDING YOUR PV SYSTEM

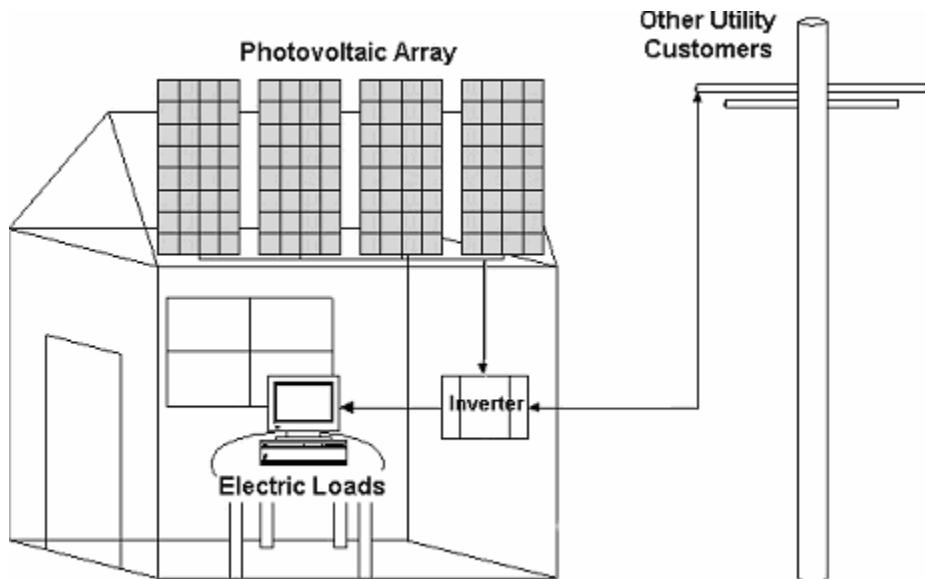
Before presenting the Solar Learning Lab™ to students or the public, it is important to understand the PV system to which it is connected. PV systems come in a variety of shapes and sizes, from the traditional panels, to shingles to glass laminates. Despite their different appearances, there are a few things that all PV systems have in common.

All PV systems use semiconductor technology to produce electricity from the sun's rays. In fact, the same type of silicon wafers that are used to make computer chips can be used to create electricity. When the sun's rays fall on the PV cell, it increases the energy stored in the atoms of the wafer. That increased energy knocks electrons loose and when conducting wires are attached to the cells, electricity flows. PV cells are

wired together to make a module, and these modules are connected into larger arrays. Solar arrays are usually mounted on rooftops or on a ground mounted structure.

When PV is exposed to sunlight it produces direct current (DC). In order for the electricity to be used to power most household appliances, it must be converted to alternating current (AC). The piece of equipment that accomplishes this conversion is called an inverter. Once the electricity is converted to AC, it flows into the building and is used for lighting, appliances, etc. In most urban or suburban settings, the building is also connected to the electrical grid. In this case, if the PV system is not producing enough electricity for the building, more can be purchased from the utility. On the other hand, if any excess power is generated it can be sold back into the electric grid for use by other electric customers. (In many rural applications, particularly in developing countries, buildings are not hooked up to the electrical grid and no power is available beyond what is produced by the PV system).

Diagram 1. Basic PV System Components



SOLAR LEARNING LAB™ COMPONENTS

Solar Learning Lab™ is the term used to describe a PV system integrated with a Heliotronics educational monitoring system. The monitoring system is designed to bring informative data about your PV system to a kiosk or computer display. Students and visitors in your building can view the data and interact with the PV system through this display using the *SunViewer™* software. The data being displayed is gathered by a data monitor that is connected to the PV system and a cluster of meteorological instrumentation.

EXPLORING THE DATA DISPLAY

Getting Started

To open the *Sunviewer™* software, double-click the *Sunviewer™* icon on the desktop of your computer. If the *Sunviewer™* icon is not on the desktop of your computer then click on the Start menu, select Programs, and then click on *Sunviewer™* in the program list.

Software Map

Below is a basic outline of the pages in the *SunViewer™* software.

I. Home Page – Solar Learning Lab™

1. What does it Look Like?

- a. Solar Modules
 - i. Land Use
- b. Switch Gear
 - i. Inverter
 - ii. AC Disconnect Switch
 - iii. DC Disconnect Switch
- c. Balance of Systems
- d. Data Acquisition System
 - i. Primary Weather Cluster
 - 1. Wind Vane
 - 2. Anemometer
 - 3. Ambient Temperature Sensor
 - 4. Module Temperature Sensor
 - 5. Pyranometer
 - ii. Secondary Weather Cluster
 - 1. Rain Gauge
 - 2. Barometer
 - 3. Relative Humidity Sensor
 - iii. Display Computer
 - iv. Data Monitor
 - v. Electrical Measurements
 - 1. Power Monitor
 - 2. Energy Meter

2. Why Choose Solar?

- a. Avoided Emissions
 - i. Global Warming
 - ii. Emissions from Automobiles
 - iii. Plants and Carbon Sequestration

3. What is it Doing?

- a. Monitoring Center
- b. Current Weather

- c. Plotting
 - d. Data Capture
4. How Well is it Performing?
- a. Inverter Efficiency
 - b. System Efficiency
 - c. Array Efficiency

Page-by-Page Details

When you first launch the SunViewer software, you will be taken to the homepage. From here, the software is divided into four major sections.

1. What Does It Look Like?

This section of the software identifies each component of a solar PV system. It is a virtual tour of the solar PV system. Students can discover the inner-workings of PV and data monitoring systems. Click on the buttons to see photos and explanations of the hardware used to harness solar energy and monitor weather.

[What Does It Look Like?](#)

What Does It Look Like?

This Page Shows a Solar Learning Lab

Click on the Buttons to Learn About the Different Parts of the System and How They Work

Solar Module

Switch Gear

Balance Of Systems

Data Acquisition

HOME

2. Why Choose Solar?

From this page you can view the Avoided Emissions for your system, investigate the environmental benefits of solar energy, and read about global warming, automobile pollution, and the role of trees in the carbon cycle. PV systems connected to the utility lines are reducing the amount of electricity consumed from large power plants. These large power plants are typically powered by fossil fuels which are known to pollute the environment. Your PV system is essentially displacing "dirty" electricity produced from fossil fuels with "clean" energy produced by photovoltaic panels.

Why Choose Solar?

Why Choose Solar?

This Shows How Much Pollution Has Been Avoided Due the Use of This Solar Array

Click the Pictures to Learn More About Pollution and its Effects

FOSSIL FUEL POWER PLANT



Since System Was Installed

Cumulative System Energy in Kilowatt Hours

Carbon Dioxide in kilograms

Sulfur Oxides (SOX) in kilograms

Nitrogen Oxides (NOX) in kilograms

A solar array converts sunlight to electricity without polluting the air. This display shows how much pollution has been avoided due to the electricity generated by this solar array.

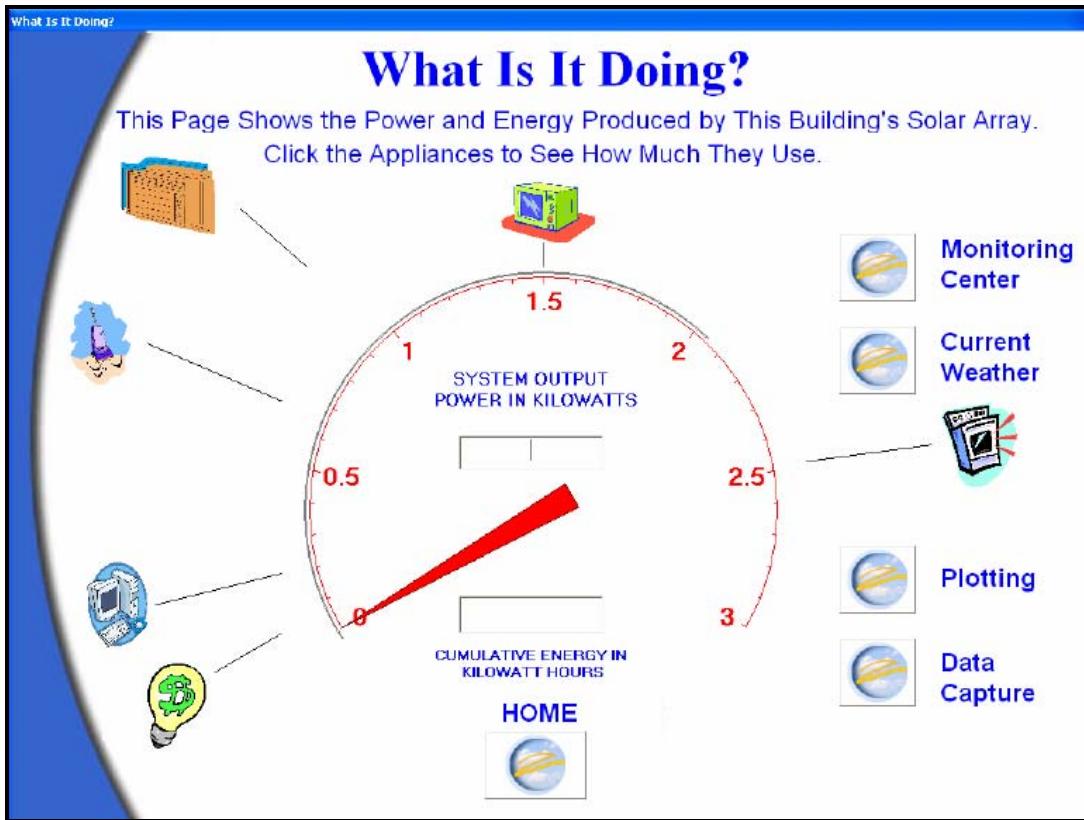
  

HOME

This page shows the amount of pollutants displaced by your PV system. At the bottom of the page are icons that introduce students to global warming, automobile emissions, and carbon sequestration by plants.

3. What Is It Doing?

Click on the button that says "What is it Doing".



The focus of this page is the power meter. This meter shows how many kilowatts of power are being produced at any given time. In the center of the meter you can see the numerical readout for the meter. At the bottom of the meter is a numerical readout showing how many kilowatt-hours of energy have been produced since the system was installed.

The power meter is shaped like a speedometer so that students can better understand the mathematical relationship between power and energy. It's the same relationship as speed and distance.

For a speedometer the relationship is:
 $\text{Speed} \times \text{Time} = \text{Distance}$

For the power meter the relationship is:
 $\text{Power} \times \text{Time} = \text{Energy}$

You can see that the energy reading is similar to the odometer reading on a car.

Around the outside of the power meter are icons that show how many watts are used by different appliances, including a hairdryer, electric oven and a computer. Students can click on each appliance to learn more about their energy consumption.

An Example of Power vs. Energy

A light bulb requires 60 watts of power. If the light bulb is left on for one hour then it has used 60 watt-hours of energy.

From this page you can link to four other pages: Monitoring Center, Current Weather, Plotting, or Data Capture. From any of these pages you can use the back key or the Home key to return to the homepage.

A. Monitoring Center

This page provides access to all of the real-time data readings for all solar energy and weather instrumentation.

B. Current Weather

This page provides access to all of the real-time data readings for the weather instrumentation.

C. Plotting

On the plotting page, students can view graphs of the solar intensity, energy output power, module temperature and system efficiency for a 24 hour period of time. On the left, select the day you would like to see.

D. Data Capture

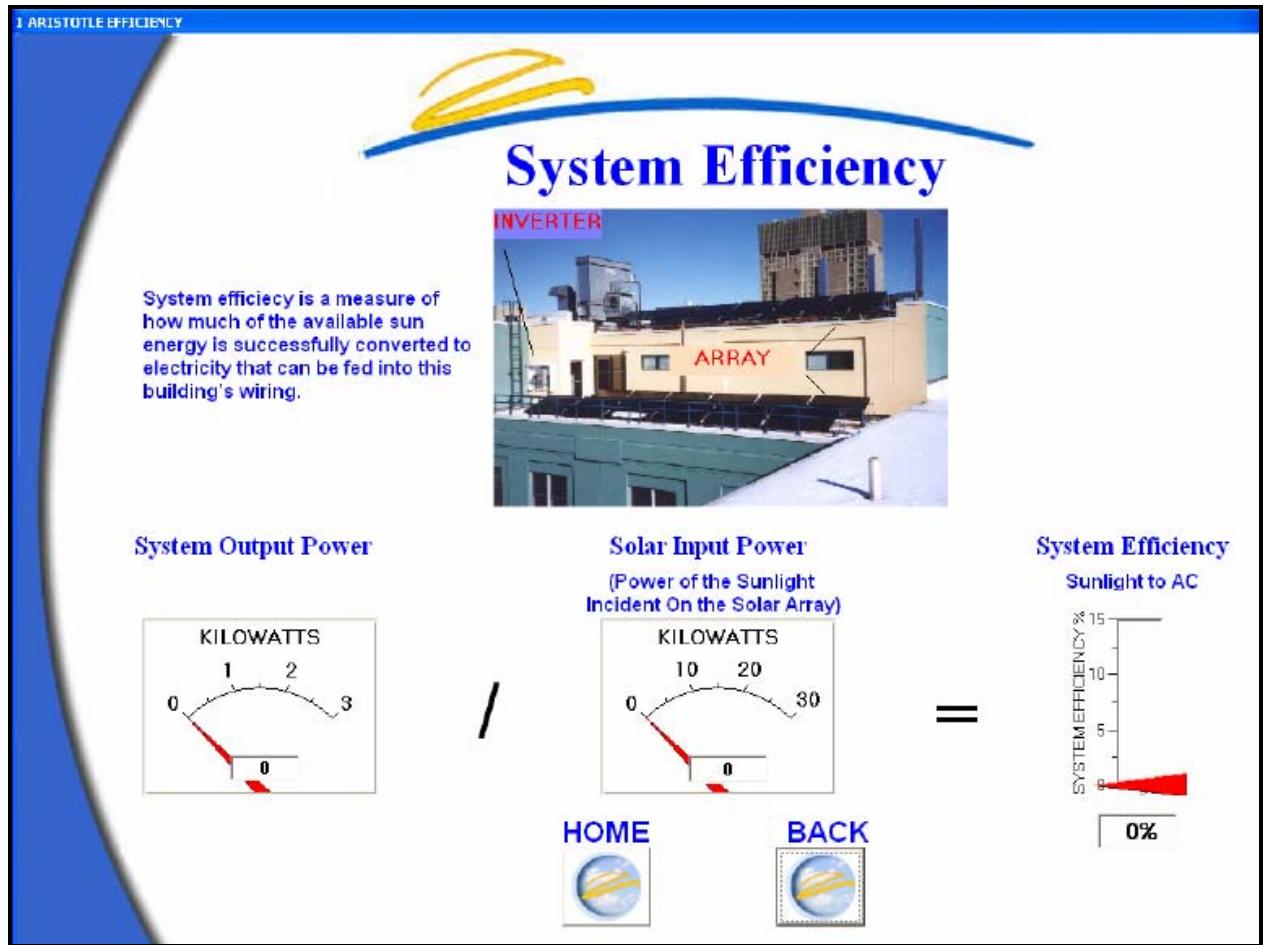
The data capture feature allows students to take a “snapshot” of the data that they would like to analyze. Since the data is real-time and constantly changing, it is convenient to use this feature to freeze the data at any given point in time. Select the checkboxes next to each variable that you would like to freeze and then press the Data Snapshot button at the bottom of the page. This is helpful for manual plotting exercises where the students can use the data capture page to obtain data points and then create their own graph.

4. How Well is it Performing?

This section of the *SunViewer* software displays calculated real-time efficiencies. Users can learn the equation for calculating the efficiency of a system. This page shows a general schematic of the PV system.

A. System Efficiency

Photovoltaic systems convert energy from the sun into usable alternating current (AC) electricity. All technologies that convert one form of energy to another can be rated in terms of efficiency. As the PV system converts sunlight (photons) into AC electricity, not all of the energy from the sunlight is captured. The solar panels themselves do not use the entire spectrum of sunlight energy (in fact they only capture about 10-20% of the energy in sunlight!) Small amounts of energy are also “lost” in the inverter when converting DC electricity to AC electricity. Click on the System Efficiency button to see the mathematical calculation of efficiency for your PV system.



You can also see the efficiency of your PV array and inverter (some systems may not have this functionality). It may be of interest to compare the efficiency of other systems such as an automobile engine or a fuel cell.

EDUCATING WITH SOLAR DATA

The Solar Learning LabTM provides a source of data that can be used to teach about energy, environmental issues, weather, math, etc. There are several resources available to teachers looking for lesson plans and curriculum ideas.

Curriculum Resources

- www.schoolpowernaturally.org
- www.need.org
- www.wattsonschools.com
- www.eere.energy.gov/roofus/
- www.fsec.ucf.edu/ed/sm/

GLOSSARY OF TERMS

Ambient Temperature - The temperature of outdoor air surrounding the solar modules.

Amps – a unit of measure for electrical current.

Anemometer – sensor used to measure wind speed. Put in a picture

Array – A number of solar panels/modules mounted together in close proximity form a solar array.

Array Efficiency – This is a measure of how much DC power was produced in comparison to the amount of sunlight that was hitting the modules. The array efficiency is equal to the DC current produced by the system divided by the power of the sunlight hitting the modules.

Avoided Emissions – The electricity you purchase from the electrical utility often comes from power plants that burn fossil fuels (namely oil, coal and gas). These power plants release carbon dioxide, nitrous oxides and sulfur oxides into the atmosphere. When you use power from a PV system no pollution is produced. Therefore, you have avoided putting those harmful emissions into the air. The Solar Learning Lab™ calculates the amount of carbon dioxide, nitrous oxides, and sulfur oxides emissions that you have avoided. This formula is based on the national average power supply (do we know percentages?). To learn more about exactly where your power supply comes from, contact your utility company.

Carbon Dioxide (CO₂) – Carbon Dioxide is an atmospheric gas. Scientists have noted an increasing amount of Carbon Dioxide in the atmosphere which is likely due to human activities. The burning of fossil fuels for electricity is responsible for approximately one third of all carbon dioxide emissions..

Data Logger – The Heliotronics data logger (a.k.a. Sun Logger) collects signals from all of the sensors and transducers in the monitoring system and sends the information to the personal computer running the SunServer™ software. In the Heliotronics system, the data logger doesn't actually log any data (excluding kilowatt-hours) but rather converts signals into data that is stored on a personal computer.

Data Snapshot – This feature allows the user to capture multiple data points simultaneously. To do so, the user must check off the desired data points and click on the “Snapshot Data” button. The real time column will show the time of capture and the data capture column will show the desired data. To select new data points, the user should press the clear button.

Disconnect Switch – This switch enables service personnel to disconnect the building electric service from the PV system to allow service personnel to work on the electrical service safely.

Inverter - The inverter converts the direct current (DC) coming from the solar array to alternating current (AC) that is used in the electric utility grid. In addition, the inverter performs a variety of safety functions associated with connecting directly to the utility grid.

Irradiance – The power per unit area incident on a surface. In the context of solar energy systems, irradiance refers to the solar power per unit incident on the plane of the solar modules. Solar irradiance is measured with a sensor called a pyranometer.

Kilowatts – A kilowatt (kW) is a measure of power equivalent to 1,000 watts.

Kilowatt-hour – A kilowatt-hour (kWh) is a measure of electricity consumption. One kWh is equivalent to 1,000 watt hours. This is the amount of electricity necessary to run a 100 Watt light bulb for 10 hours.

Load - The load is the amount of electricity that is being used by the building.

Nitrogen Oxides – Nitrous oxides (NOx) are pollutants that are emitted from fossil fuel power plants. NOx contribute to the problem of global warming and are also responsible for the formation of surface level ozone, better known as smog.

Pyranometer – sensor used to measure solar irradiance/solar intensity.

Solar Intensity – the amount of power per unit area of sunlight incident on the plane of the array, measured in watts per square meter.

Solar Modules - A solar module, commonly referred to as a solar panel, is made up of solar cells wired together in series.

Sulfur Oxides - Sulfur oxides (SOx) are pollutants that are emitted from fossil fuel power plants. SOx contribute to the formation of acid rain.

SunServer™ – Heliotronics software that “serves” the data to SunViewer™. Only the system administrator should need access to SunServer™.

SunViewer™ - Heliotronics educational display software. This is where the users can view the data and learn about how the solar photovoltaic system works.

Volts- A unit of measure for electrical voltage.