Section 3: Your School's Solar-Electric System

SECTION 3: Activities

Solar Energy Powering Your School

A portion of the energy needed to run your school is coming from renewable, solar energy. Whether the solar-electric system is mounted on the roof or on a pole, the energy it creates is offsetting power that would otherwise be delivered through a fossil fuel source such as coal or oil. Every watt of renewable energy created by your school's solar-electric system reduces the amount of nonrenewable energy your school uses.

In this section you'll learn about your solar-electric system's components so you can recognize them and understand their function. Pieces of the solar-electric system may be located in various parts of your school. For example, the photovoltaic (PV) panels may be on the roof, the inverter might be mounted in the gym, and the kiosk (if applicable) may be in the lobby or student lounge.

We'll also address common questions you might have about your school's solar-electric system. For example, how much power does the system produce and what kind of equipment can it power? While the solar-electric system on your school isn't capable of providing energy for all of your school's needs, you might be surprised at how much energy your solar panels produce.

You can help ensure that your solar-electric system is operating at its maximum potential by becoming familiar with the system components and by monitoring it regularly. Bonneville Environmental Foundation will be watching your system as well, but your daily interaction with the system and personal experience with weather in your area is invaluable to the ongoing success of the Solar 4R Schools (S4RS) program.

What Components Make Up Our School's Solar-Electric System?

PHOTOVOLTAIC MODULES:

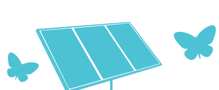
- Number of panels: 6
- Panel power: 170 watts
- Array power: 1,020 watts (about 1 kW)
- Panel size: 5' x 2.5'
- Array size: 5' x 15' or 10' x 7.5'
- Weight: 37.5 lbs x 6 = 225 lbs

SYSTEM EQUIPMENT:

- 170 watt PV modules
- 1800 inverter
- Mounting rack and hardware
- Direct current (DC)/ alternating current (AC) wiring conduit
- Communications gateway
- Weather station
- Direct Current and AC disconnects
- Communications wiring
- Production or load meter

How Does Our Solar-Electric System Work?

1. Energy from the sun hits the solar panels in the form of photons.
2. The solar panels produce direct current (DC) electricity.
3. Direct current electricity flows through electrical cables from the panels to an inverter.
4. The inverter converts the electricity from DC to conventional alternating current (AC) power.
5. The inverter is connected to an electrical service panel at your school and measures the amount of energy produced by your solar-electric system.
6. Alternating current power is compatible with the electric utility grid and may either be used at your school or fed back into the grid through a process called net metering. Net metering is a method of crediting customers for electricity that they generate on site in excess of their own electricity consumption.
7. The inverter is connected to a Data Acquisition System (DAS), also called a communications gateway.
8. The DAS transmits information about your solar-electric system to the internet so you can monitor your system and download data.



What Are the Key Components of Our Solar-Electric System?

solar panels – Photovoltaics used to capture sunlight and convert it into electricity.

direct current (DC) disconnect – Cuts the flow of current from the solar panels to the inverter.

inverter (power conditioning) – Converts DC electricity to AC electricity that can be used in your school.

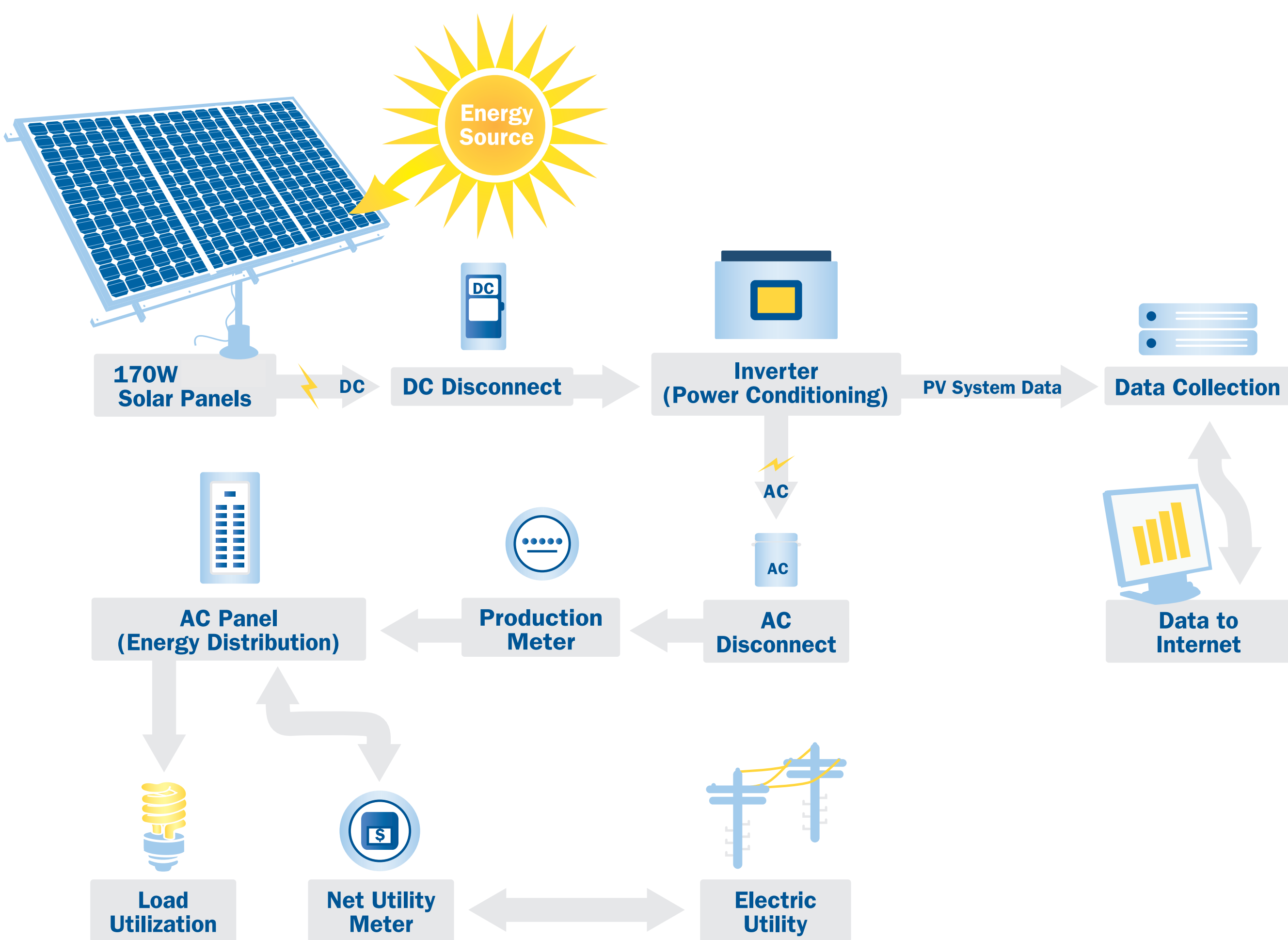
alternating current (AC) disconnect – Cuts the flow of current from the inverter to the service panel.

production meter – Logs electricity generated by the photovoltaic system.

alternating current (AC) panel (energy distribution) – Transfers power from the utility line to the school or from the school to the utility line.

net utility meter – Logs the total amount of electricity the school uses, which equals the electricity provided from the grid minus the electricity generated by the solar panels.

data collection – Gathers system data and relays the information to the internet.



What Is an Inverter?

The inverter is often thought of as the mother brain of a PV system. As this technology advances, the inverter is doing more and more of the work necessary to properly operate a system. The primary job of the inverter is to convert DC electricity to AC electricity. Photovoltaic modules generate only DC power, and batteries used to stored solar energy in off-grid situations also only generate DC electricity. Alternating current electricity is used by our homes and is the form of current that feeds the energy grid from which power is drawn. Direct current and AC electricity are fundamentally incompatible therefore an inverter is needed to transform the electricity.

Why Is Our Solar-Electric System Located Where It Is?

Bonneville Environmental Foundation performs a site assessment to determine the best place to locate a solar-electric system at a school. The first step in determining the location of the system is orientation. The PV system should be situated so it is able to gather as much energy as possible throughout the course of a day and over the course of a year. Generally, a PV system should be oriented south. On the eastern coast of the United States, orienting a PV system to the south-east can also provide sufficient sunlight if the direct southern sun path is obstructed. On the western coast of the United States, orienting a PV system to the south-west will also provide sufficient sunlight if the direct southern sun path is obstructed.

When performing a site assessment, it is important to make sure obstructions that may create shading on the PV system are addressed. Shading solar cells on an individual solar module will dramatically reduce the energy output of the solar array. Shading modules in an array essentially shuts down all electricity from the shaded string of modules. This is like taking one battery out of a series of batteries in a flashlight.

How Are Sun Charts Used in Solar Site Assessments?

Sun charts are used to identify when objects will block a collector from direct sunlight. Sun charts plot the sun's elevation angle and azimuth angle over a day, as seen from a given location. The elevation angle measures the height of the sun in the sky from the horizon; it's the complement of (i.e., 90° minus) the zenith angle of the sun. The azimuth angle indicates the direction of the sun in the horizontal plain from a given location. North is defined to have an azimuth of 0° and south has an azimuth of 180°.

Sun path charts can be plotted either in Cartesian (rectangular) or polar coordinates. We are most familiar with Cartesian coordinates where the solar elevation is plotted on one axis and the azimuth is plotted on the other axis at right angles to the first axis. Polar coordinates are based on a circle where the solar elevation is represented by smaller and smaller circles as the elevation increases, and the azimuth is the angle going around the circle from 0° to 360° degrees.

How Is Our Solar-Electric System Mounted?

Each Solar 4R Schools system is mounted according to the unique situation at the location. Most schools have a large roof space perfect for mounting solar panels. Other schools, while they may have a large roof space, also have large trees that create too much shading on the system. In these situations a ground-mounted system can be used. A ground-mounted system is simply a set of PV panels connected together to form an array that is mounted on a pole several feet off the ground in a location free from obstructions.

Other mounting methods include integral mounting, standoff mounting, and rack mounting. Integral mounting is where the modules are integrated into the roofing or exterior of the building itself. Standoff mounting is where modules are mounted above and parallel to the roof surface. For flat roofs, standoff mounting may be used for small arrays. Large-scale flat roof commercial projects are often accomplished with fully engineered and certified systems, and some have no roof penetrations. The most common mounting method on a sloped roof is the standoff mounting method, as this method provides for air circulation behind the modules to reduce PV module operating temperature.

How Much Power Does Our Solar-Electric System Produce?

Under peak-sun conditions, a standard 1 kilowatt PV array will produce 1,020 Watts of electric power, which is about enough energy to power 77 energy-efficient light bulbs. Of course, the amount of power being generated is proportional to the amount of sunlight hitting the array. On a dark, cloudy day the panels could produce fewer than 200 watts even at solar noon when the sun is highest in the sky.

Is That Enough Power to Run a Classroom?

Your school's solar-electric system will not be used to power any single device or classroom. Since the system is grid-tied, it is helping to power everything at the school. To help students understand how much power is being generated, you could monitor the power use of individual devices and compare that to the power output of the panels. On a sunny day, your system could produce enough power to operate the following devices at the same time:

APPLIANCE	WATTS
Ceiling Fan	60
Clock	5
Computer (Monitor & Printer)	200
4 Compact Fluorescent Bulbs (14 W Each)	56
Refrigerator	300
Sewing Machine	75
Stereo	30
Television	180
Video Cassette Recorder	40
TOTAL:	946

However, instead of using all of these devices at the same time, you probably turn them on and off as you need them. Your solar-electric system will also be generating power on the weekends and when school is out of session; therefore, it is necessary to store the excess power generated by your solar-electric system.

How Is Solar Energy Stored?

Solar energy can be stored in the utility grid or in batteries. Today, most solar energy is stored in utility grids by connecting the solar-electric system to the service panel, which is called grid-tying the system. Storing energy in the grid reduces the overall cost of energy to consumers by saving utilities additional costs they incur during peak energy use hours when more facilities power up to meet energy demands. Energy is more expensive at peak hours. For example, energy prices go up in the middle of hot, summer days when the energy grid is stretched thin by widespread use of air conditioning equipment. Since solar energy is also at peak production during the peak hours of summer days, the energy generated by solar-electric systems helps offset the additional costs of purchasing energy during these peak hours.

For homeowners and businesses with solar-electric systems, storing energy in the grid also provides energy credits in many areas of the United States. An energy credit is incurred when a solar-electric system generates more power than the home or building can use. The excess power exits the solar-electric system via the service panel connection and returns to the utility grid. When excess power is generated, the kilowatt meter turns backwards and the utility company credits the account for the energy generated. These credits help offset annual energy costs for the house or building. For example, if a house generates extra energy in the summer, energy credits can offset the house's higher use of energy in the winter when there is less potential to harvest solar energy for electricity.

Solar energy can also be stored in batteries. When a solar-electric system stores its energy exclusively in batteries, it is called a stand-alone system. Stand-alone systems are an ideal way to store solar energy for people who live in remote locations. Batteries can also be integrated into a grid-tie system to provide a backup power source for power outages. In this hybrid system, the building gathers energy from the solar-electric system and the grid during normal use, but should the grid lose power, the building will immediately draw power from an additional battery supply.

How Can We Monitor Our Solar-Electric System's Performance?

The S4RS website is a great place to closely monitor your school's solar-electric system. You can also use the website to monitor data from other schools in the program. To access a school's system data:

1. **Go to the S4RS website (http://solar4rschools.org/).**
2. **On the home page, locate your school in the "Choose a School in Your Program" menu.**
3. **You have the option of viewing information in three tabs: Production, Specs, and Photos.**

4. **To the left of these three tabs is a "Search Data" magnifying glass that allows you to search and download information from your school's system or from any school in the program. The "Search Data" page will ask you to set the parameters for three fields:**

   I. Period. This section gives you the option of looking at data from a school system over the course of a day, week, or month. You also have the advanced option of choosing the timeframe you wish to view for a system, and you have the option of viewing the entire life of a system.

   II. Data. This section shows the aspects of the systems monitored by S4RS:

   - **Ambient Temperature** refers to the temperature of the air in the vicinity of the solar-electric system and is measured in degrees Celsius (°C).
   - **Building Data** (not available for all systems) provides details on how much energy has been used by the solar-electric systems.
   - **Irradiance** is the amount of radiant energy from the sun over all wavelengths that fall to Earth's surface at any instant in time. The maximum typical irradiance on a square meter of Earth is 1,000 Watts.
   - **Cell Temperature** refers to the actual wafers of silicon (i.e., the PV cells) within the solar panel that is generating electricity. If cell temperature gets too high, it can adversely affect the solar-electric system output. Cell temperature is measured in degrees Celsius (°C).
   - **PV Output** refers to the amount of electricity produced by a solar-electric system and is measured in kilowatts DC (kWDC).

   III. Site. Allows you to select which school(s) you want to see data for.

In addition to the website, the Activity Guide CD provides activities that teach students how to download data from the website and familiarizes them with the terms related to your school's solar-electric system.

How Does Our School's Solar-Electric System Compare to a Home's Energy Use?

An average U.S. home uses about 10,000 kWh per year, which is more energy per household than almost any other country in the world. Under normal conditions, a 1 kW PV array produces about 1,100 kWh per year, which is about 10-15% of an average U.S. household's annual electricity needs. However, if a household implemented energy-saving measures such as energy conservation and energy-efficient upgrades,
a 1 kW solar-electric system could provide more than 50% of the annual energy needs. You can find out how much energy your household uses by checking your utility bill.

What Should We Do if Our Solar-Electric System Stops Working or Isn't Working Correctly?

You can monitor the long-term health of your school's solar-electric system on the S4RS website. In the event that your system stops operating or transmitting data to the website, please contact a specialist from Bonneville Environmental Foundation's (BEF) S4RS team. In most situations BEF will be aware that the system is not operating correctly as soon as the problem occurs.