UT Extension

E³A: Solar Electricity for the Home or Farm

SP 758-E

Steps in the Solar Electricity Series

STEP 4

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System Components

Photovoltaic (PV) Materials

Photovoltaic (PV) materials are the electricity generating component of a solar electric system. Commercially available PV materials include crystalline silicon panels and thin-film materials that are both made in various sizes with various wattages of PV modules. When the sun's light energy (not heat energy) hits and is absorbed by PV cells, electrons are released and flow as direct current (DC) electricity. The greater the intensity of the sunlight, the more electricity is generated by a PV cell.

On partly cloudy days, PV materials will produce about 80 percent of their rated capacity. Extremely overcast days may reduce electricity output to 30 percent or less of rated capacity. PV materials are relatively unaffected by severe weather and temperatures, although like most electronic devices, they operate more efficiently at cooler temperatures. PV modules are designed to resist hail damage (one name brand panel is tested to withstand 1-inch hail at 51 mph). They typically come with a 25-year power output warranty, but most will produce electricity for 30-plus years.

Crystalline Silicon

Crystalline silicon flat-plate panels range in size and electrical output and can be used for a variety of applications. Those typically placed on home rooftops range from about 2 to 3 feet wide by 4 to 5 feet long with a 3-inch thickness. Electrical output ranges from less than 100 to 300 watts.

Multi-crystalline silicon PV panels on a rooftop. Four, 250-watt PV panels = 1,000 watts = 1 kilowatt (kW). Together, they produce 1 kWh of electricity per hour in direct (peak) sun. If the panels get four hours of direct sun, the system may produce 4 kWh that day.

Courtesy of DOE/NREL

Thin-Film PV

Thin-film PV materials are flexible and versatile for a variety of applications. They are made by spreading silicon and other materials in a very thin layer (human hair thickness) directly onto base materials, making them ideal for building-integrated products such as roof shingles, tiles, building facades, windows and skylight glazing. A third generation of new solar materials includes lightweight foil-based panels, solar inks and dyes, and conductive plastics. Researchers continue to investigate how to make all PV materials more efficient at converting sunlight into electricity.

Photovoltaic Material Types	
Crystalline Silicon	**Single-Crystalline Silicon** Also called Monocrystalline • Made from a single, large silicon crystal • Most commonly used • 15-20%+ efficient: currently the most efficient material for converting sunlight into electricity • Costs more per watt than multi-crystalline, less than thin-film
	Multi-Crystalline Silicon Also called Polycrystalline • Made from silicon blocks with many small crystals • 10-15% efficient • Costs less per watt than single-crystalline and thin-film
Thin-Film	**Thin-Film Types** Amorphous silicon and non-silicon materials such as Copper Indium Gallium Selenide (CIGS) and Cadmium Telluride • 6-10% efficient • Currently costs more per watt than both crystalline silicon types

If your building does not have a south-facing roof or surface (or you cannot use PV modules as structure), panels can be ground-mounted or pole-mounted in a yard or field. Pole-mounted panels can be in a fixed in a south-facing position or placed on tracking devices. Like sunflowers, tracking devices follow the sun's skypath. A single-axis tracker follows the sun from east to west. A dual-axis tracker follows the sun from east to west and adjusts for seasonal sun angles. Trackers increase system installation cost and do require maintenance, but can increase power production by 20 to 30 percent. For the more hands-on homeowner or building manager, adjustable rooftop mounting structures are available for making seasonal sun angle adjustments.

Courtesy of Solar Plexus, LLC

PV Material/Panel Performance

Manufacturers provide a minimum warranted power rating (in watts) that may be called peak power or peak tolerance rating, etc. Many panels are tested under either Standard Test Conditions (STC) or PVUSA Test Conditions (PTC). The main difference is the testing temperatures. A PTC rating is deemed a more realistic rating. If the panels you are considering have an STC rating, actual performance may be 85-90 percent of stated wattage output.

System Performance

When sizing your PV system, use the rated wattage output (referred to as nameplate DC [direct current] rating) of the panels to estimate the number of panels needed to meet your targeted electrical output. Actual output of electricity will depend on factors such as roof orientation, tilt angle and overall system efficiencies. Because there are inefficiencies in the remaining components (wiring, inverter, etc.), a de-rate factor is calculated based on the efficiences of the individual components. To calculate overall efficiency, multiply the PV panel nameplate DC rating by 77 percent (a conservative de-rate factor used in NREL's PV Watts online tool) for an estimate of the amount of electricity that will actually be produced. For example: A 230-watt DC Nameplate rating x .77 = approximately 177 watts of actual electrical power will be delivered. Note: Overall de-rate factors may be higher or lower with specific panels and components. Always discuss with your installer or supplier/manufacturer the specific inefficiences of each of the components to achieve a more accurate calculation.

Balance-of-System (BOS)

Balance-of-System (BOS) is a term that refers to the remaining components that accompany PV panels. BOS includes the inverter(s), meter(s), safety equipment (disconnect switches, etc.), batteries and a charge controller. It also includes conduit, cables and combiner boxes.

Inverter

All PV materials/panels produce DC electricity, which can be used for DC-powered appliances and camping and boating-related equipment, etc. Most appliances, electronics and machinery require alternating current (AC) electricity, and an inverter converts the PV-generated DC into AC electricity. Inverters also "condition" the PV-generated electricity to match the qualities of the utility grid-produced electricity for grid-tied PV systems. Contact your utility company to ask if it requires a specific Underwriter's Laboratories (UL)-certified inverter.

Inverter/Charger

For systems with batteries, a combined inverter/charger may be used. It converts PV-generated DC current and/or current from the batteries to AC current, and it allows batteries to be charged by the utility grid or an off-grid system's back-up generator by converting the utility's or generator's AC current to DC current for battery storage.

All solar electric system components must be matched to work together as a system. If you plan on adding more PV panels at a later date, size your inverter for the future system. It will be less expensive than upgrading to a larger inverter and the accompanying equipment changes that would also be required. Inverters should be accessible, weather-protected, and kept out of direct sun. Inverters can be up to 98 percent efficient and last up to 20 years. Warranties are typically for 10 years.

Some installers will connect microinverters to each individual PV panel instead of installing one larger inverter. Micro inverters work well where there might be potential panel shading because each panel works independently of others, allowing unshaded panels to continue to function. They can make system expansion easier and less expensive.

Meters

Meters track the amount and "direction" of electrical flow in grid-tied systems (off-grid systems often have meters to track battery charge levels, etc.). The PV system generates electricity whenever the sun is shining. If your building or machinery does not use all of the electricity being generated at any one time, the surplus electricity is fed into the utility's grid. When this occurs, you are credited at either a retail or wholesale rate from the utility for that amount of surplus electricity. The retail rate is the rate you pay for electricity from the utility. The wholesale rate is a lower rate the utility pays for electricity it buys on the market.

How is grid-tied system electricity tracked? In the TVA network, a dual-metered system is used where one meter tracks the PV-generated electricity that is fed into the grid, and another meter tracks the electricity you purchase from the utility. If at the end of a billing period you used more electricity than your PV system generated, you pay the utility company. If your PV system generated more than you used, you receive a utility credit. Contact your utility company to determine if it allows connection to the grid. If it does, ask for current interconnection and dual metering requirements. Your PV system installer will also be familiar with the requirements.

Safety Equipment

Safety equipment protects buildings and their owners, utility workers and system equipment. Safety equipment includes AC and DC disconnect switches, circuit breakers and fuses, grounding equipment, and surge protection. This equipment is very important for protecting people and system components from power surges, lightning strikes, ground faults and equipment malfunctions. Automatic and manual disconnect switches are recommended. Disconnect switches shut down the system so it can be worked on safely whether for routine maintenance or repairs. Switches also prevent the system from sending power to the grid and endangering utility workers while they conduct repairs.

Charge Controller

A charge controller regulates battery charging. When batteries are part of a solar electric system, a charge controller, also called a regulator, is required. It is connected between the PV panels and the batteries to regulate and optimize current and voltage to the batteries, keeping batteries fully charged and preventing battery overcharging. It also prevents batteries from being excessively discharged, which can damage or ruin them. Charge controllers must be properly matched to the overall solar electric system for proper function. Charge controllers can be up to 98 percent efficient and are typically warrantied for up to five years. Inverters and charge controllers can be combined into one piece of equipment.

Batteries

Batteries store electricity. Off-grid buildings require batteries as part of the solar electric system. Electricity is stored and used from the battery bank, which is sized to provide electricity for the full electrical load for two or three days. Grid-tied buildings with battery back-up typically have a small battery bank used to store electricity for use during brief utility power outages. Batteries can lower the overall efficiency of a solar electric system because they only release a percentage (80-95 percent) of the electricity that is fed into them. Batteries need periodic maintenance and have safety considerations. They may last from seven to 10-plus years before requiring replacement. Lifespan depends on factors such as depth of discharges, number of discharges and the temperature where they are used.

Whether installing a solar electric system to power a building or pump water, make sure to purchase quality, certified components.

Component and System Certifications

- PV panels: Underwriter's Laboratory (UL) 1703 safety standard.
- Inverters and Charge Controllers: UL 1741.

Organizations that test and certify system components:

- The Florida Solar Energy Center (FSEC): www.fsec.ucf.edu
- Go Solar California: www.gosolarcalifornia.org (Equipment Section)

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Notes

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