Photovoltaics

Systems that Convert Sunlight to Electricity Can Meet Many Different Needs

Photovoltaics is a technology that converts radiant light energy (*photo*) to electricity (*voltaics*). Photovoltaic (PV) cells are the basic building blocks of this energy technology.

PV cells (also called *solar cells*) are made of semiconductor materials, most typically silicon. The amount of electricity a PV cell produces depends on its size, its conversion efficiency (see box on reverse), and the intensity of the light source. Sunlight is the most common source of the energy used by PV cells to produce an electric current.

It takes just a few PV cells to produce enough electricity to power a small watch or solar calculator. For more power, cells are connected together to form larger units called *modules*. Modules, in turn, are connected to form *arrays*, and arrays can be interconnected to generate electricity for a large load, such as a group of buildings.

Single-crystal silicon is the most common semiconductor material used in making PV cells. Polycrystalline silicon, in the form of a thin film or coating on an inexpensive base of glass or plastic, is also used, and PV modules can also be made of thin films of amorphous (noncrystalline) silicon. Thin films are usually less expensive to manufacture because they require less silicon and the process is less labor-intensive. PV devices are also being developed using combinations of other materials, such as cadmium, copper, indium, gallium, selenium, and tellurium.

PV modules are typically installed on or near a building or other structure. They can also be specially designed as an integral part of a building's roof, wall, skylight, or other element. This is called *building-integrated PV* or *BIPV*.

What are PV energy systems?

A PV energy system usually includes a module or array and the structural hardware needed to install it. The simplest PV systems generate DC electricity, usually for a small load, when the sun is shining or they are exposed to artificial light. More complex systems include a power inverter that converts the direct current (DC) generated by PV to alternating current (AC), and batteries that store energy for use at night or when the sun isn't shining.

Today, PV is used primarily for cathodic (corrosion) protection, traffic warning lights, water pumping for irrigation and livestock, telecommunications, security and lighting systems, resource monitoring, and electric load management. Many of these uses are remote (or off-grid) power generation applications, not connected to utility power lines. PV systems are already used in many off-grid applications in the Federal government, such as for emergency call boxes near interstate highways.

When the electricity required for a Federal application exceeds the amount a PV system can supply, a conventional electric generator can be added to create a hybrid PV/generator system. Wind systems can also be added. PV systems actually have many benefits:

- Portability—many kinds of PV systems can be moved about easily.
- Reliability—they operate for long periods with little maintenance.
- Low operating costs—the fuel is free and there are no (or few) moving parts.
- Low environmental impact—they are quiet and nonpolluting (no greenhouse gas emissions).
- Stand-alone capability—they operate in remote areas far from power lines.
- Modularity—power output can be increased by adding more modules.
- Safety—they are not flammable and meet National Electric Code requirements.
- Versatility—they operate well in almost any climate.
- Short lead time—prepackaged PV systems are available, and utility easements aren't needed.
- Ease of installation—no heavy construction equipment is required.

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PV-powered security lighting at Roosevelt Lake in Arizona.

What are some opportunities for using PV in the Federal government?

Photovoltaics is a good choice for remote applications in which the daily electric load falls somewhere between a few watt-hours and about 100 kilowatt-hours. Because it is nonpolluting, PV

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should definitely be considered for remote areas that rely on fossil-fueled generators for electric power.

On a first-cost basis, the installed cost of a PV system can be less than the cost of utility service. But PV may also be a good choice in areas where the reliability of a power plant is questionable, or where an agency is being charged high rates during peak hours.

The National Park Service has installed more than 450 PV systems, chiefly to provide power for resource-monitoring equipment. These are some additional, widely demonstrated, off-grid applications for PV:

- Lights for walkways, streets, highways, and common areas
- Residential uses (fans, lights, refrigerators) in remote areas
- Electricity for campgrounds, marinas, and offshore drilling platforms
- Equipment for weather stations and fire observation towers
- Communications equipment and facilities (e.g., emergency roadside phones, microwave repeater stations)
- Cathodic (corrosion) protection for metal pipes and similar objects
- Highway and warning signs, security systems, transmission tower beacons
- Livestock watering pumps, irrigation systems, and disinfection equipment
- Emergency power during times of crisis.

What is required?

Agencies should evaluate different PV systems on the basis of cost, system performance, system reliability, and maintenance needs. These are some additional requirements:

- Modules must face south and be unshaded; they can be mounted on the application (e.g., a highway sign), on a roof, or on the ground.
- Batteries are often needed to meet peak loads or for nighttime use; they require periodic maintenance.
- Power inverters will be needed if the load requires AC electricity.

What does a PV system cost?

To determine the economic feasibility of using a PV system, agencies should consider these three main factors:

- The size and nature of the load
- The availability of the solar resource
- The cost of alternative sources of power.

What are the important terms?

Balance of system (BOS)—every element (and its associated costs) of a PV system except the modules themselves; this includes the design; land and site preparation; installation; support structures; and power conditioning, operation and maintenance, and storage equipment.

Break-even cost—the cost of a PV system at which the value of the electricity it produces equals the cost of electricity from an alternative source plus the delivery of this electricity to the site; a break-even distance is the distance a power line needs to be extended to match the installation cost of a PV system.

Peak watt—the "rated" output of a cell, module, or system; the amount of power a PV device produces when operating at 25°C during tests; the peak rating is usually determined during indoor tests rather than outdoors.

PV conversion efficiency—the percentage of available sunlight converted to electricity by a PV module or cell; technically, the ratio of electric power produced by a cell to the power of the sunlight striking the cell.

On a 20-year, life-cycle-cost basis, a remote PV system typically costs from 25¢–50¢ per kilowatt-hour. In off-grid Federal applications, PV can be more cost-effective than many alternatives. PV equipment is available from companies listed on the General Services Administration's Federal Supply Schedule (online, see **http://www.gsa.gov/regions/7fss/7fx/schedules**). The Federal Energy Management Program has developed specific Energy Savings Performance Contracts (ESPCs) that assist Federal agencies in obtaining PV systems (call the FEMP Help Desk or one of the FEMP contacts below for details).

For More Information

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