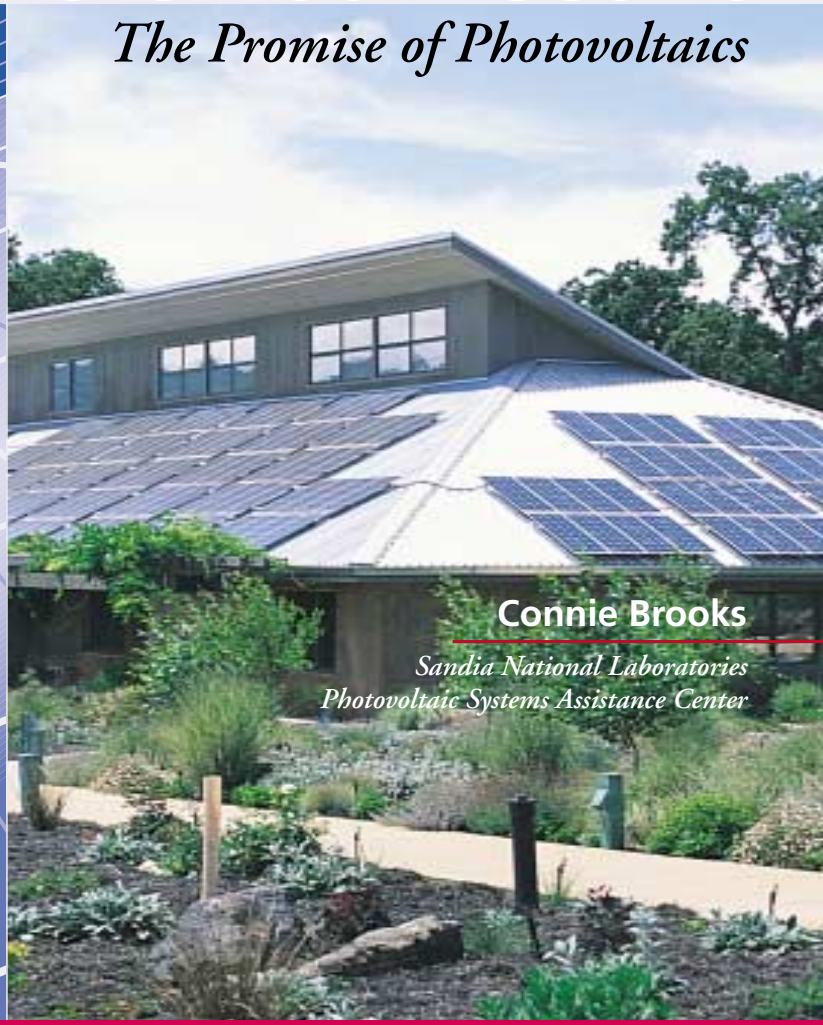
Power Where You Need It

The Promise of Photovoltaics



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Special thanks goes to Jim Rannels, Director of the Department of Energy's Office of Solar Energy Technologies, for conceiving the idea for this book. He believes that DOE and its contractors, such as Sandia National Laboratories, and the entire U.S. photovoltaics industry can benefit from a book that captures the myriad uses for photovoltaics under one cover. Thanks to Chris Cameron, manager of the Photovoltaic System Applications Department at Sandia, for his guidance during the preparation of this book, and for his vision that it should be a book about ideas, about promise, about opening our minds to photovoltaics applications not yet conceived. Several staff members within Sandia's Photovoltaic Systems Assistance Center, notably Hal Post and John Stevens, gave generously of their time; their decades of experience with PV were invaluable in helping structure, critique, and guide the preparation of this book. Finally, without the U.S. photovoltaics industry itself, this book would never have been possible. They created the successful systems illustrated here. They work daily to further the acceptability, quality, and reliability of PV. They were a huge part of the preparation of this volume. From CEOs to secretaries; from marketers to web managers, thank you for sharing your photographs and for sharing your enthusiasm.

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Cover Photo: Fetzer Vineyards, one of the largest wine makers in the United States, has decided to run all its operations from electricity generated by renewable energy. Read more about this photovoltaics installation on page seven. *[Photo courtesy AstroPower, Inc.]*

Power Where You Need It:
The Promise of Photovoltaics

For more than twenty years Sandia National Laboratories has been involved in helping establish successful programs and partnerships with members of the photovoltaics community in the United States. In large part, Sandia's efforts have fallen within the realm of engineering expertise and systems excellence. Because those efforts have been documented in numerous technical publications disseminated by the tens of thousands to industry, government agencies, educational institutions, and interested individuals, the installations with which Sandia has assisted are well known. *Power Where You Need It* is unique in that it also features dozens of installations with which Sandia has had little or no connection, except that those installations came about, in the end, because U.S. Department of Energy funding through its National Photovoltaics Program helped foster their existence. Sandia's technical expertise in systems engineering created the overarching technical framework under which many of these PV installations were made possible. Sandia, along with the National Renewable Energy Laboratory, is a partner in the National Center for Photovoltaics, which is the Department of Energy's focus organization for carrying out its National Program. Some of the installations featured in this book were made possible through various programs at the Department of Energy, but many were not. Many were simply the result of an enthusiastic end user making a vital business connection with one of the thousands of spirited members of the U.S. Photovoltaics Community. This book is dedicated to all of them. May something depicted here spur your imagination to make PV a part of the world around you.

△ Walking the talk…Secretary of Energy Bill Richardson helps inaugurate a photovoltaic system at DOE headquarters—Washington, D.C.'s Forrestal Building. *[Photo courtesy National Renewable Energy Laboratory]*

◁ The 15kW photovoltaic system at the Pentagon. The system is the largest installation of ac modules in the U.S.—operating at the largest office building in the world. The project is a joint effort of the Department of Defense and the Department of Energy. *[Photo courtesy Ascension Technology]*

Photovoltaics is a universal power source. Though still a young technology, its strength is that it can be used anywhere. This book strives to highlight the myriad ways in which photovoltaics is already being used—then expand the ways we use photovoltaics (PV). PV is an enabling technology—and it can enable us to do things never dreamed of before.

Photovoltaics—often called "solar electricity," is the direct conversion of sunlight to electricity. When sunlight strikes a PV cell, electrical current and voltage are created—silently and cleanly. Because of this, PV is one of the most attractive alternative energy forms. The modern PV cell was developed in the mid-1950s. Shortly thereafter, it powered our first space satellites, and after several decades many of these PV-powered systems are still operating—a great witness for the reliability of this power source.

Terrestrial use began to be encouraged by the U.S. government in the early 1980s. These early projects sought to prove PV's reliability and competitiveness in practical field applications. Some of those early applications, such as the Coast Guard's aids to navigation, were embraced immediately. Today PV is the prime power source for all of the U.S. Coast Guard's navigational aids. Likewise, other military and governmental applications have proven irreplaceable, remote meteorological monitoring for example.

△ Photovoltaic cells were first used in space to power a 5mW backup transmitter on the Vanguard 1 in 1958. Sputnik used PV. Indeed, solar cells power most satellites in space today, and the U.S. shuttle fleet uses PV to generate much of its electrical power *[Photo courtesy National Renewable Energy Laboratory from a Lockheed rendition]*

Enormous growth in terrestrial photovoltaics has occurred. The 21st century opens with the United States dominating the world market in PV manufacturing and technology. A presidential initiative has suggested we can have solar systems on a million U.S. roofs by 2010. The world's first PV-powered neighborhood in Gardner, Massachusetts spawned neighborhoods throughout the country, Sacramento, California being a prime example. Utility deregulation has made it possible for home-owners to install PV and sell back to their utility that portion of power generation beyond their daily needs. PV as a power source in remote areas not served by a utility was attractive from the outset and continues to create hungry markets for photovoltaics.

▽ Electric Sunflowers, a photovoltaic array in California, designed by Solar Design Associates *[Photo courtesy Solar Design Associates, Inc.]*

There are few limits to PV as a power technology. Anything that requires electricity can be powered with PV. It has become the power of choice for a vast number of telecommunications challenges worldwide.

In a fragile environment, it is often the only appropriate technology. Increasingly, it is the power of choice for utilities, commercial entities, and informed individuals.

So expand your thinking. Imagine what PV can do for you, your company, your power challenge. *Power Where You Need It* highlights many ways in which PV is being used right now—but its future is limitless. PV is truly a clean, competitive and reliable power source for the 21st Century.

ABOUT THE ORGANIZATION

Of This Book

This book is loosely organized into categories that represent how PV is used, where it is used, and by whom. This necessarily means that a reader will find lighting applications, for example, on several different pages. We mean to stimulate thinking, not structure thinking. The PV pictured here was installed for many different reasons, not all of which have to do with economics. PV is often the power of choice because it reduces greenhouse gases and provides a cleaner environment; it means less dependence on imported resources and helps conserve fossil fuels; it helps companies with their 'green' image and allows users to choose renewables; and it can provide uninterruptible building power.

There are excellent reasons why American business and industry might be interested in using photovoltaics as part of their total energy package. The installations shown here represent some of these reasons. Also depicted here is PV on schools. There is a major push to incorporate PV on schools to educate the next generation of power consumers.

Perhaps the most important economic reason for businesses to consider PV is reduction of peak demand. Electric bills for most consumers represent kilowatt hours used; but large energy consumers are also billed for their peak power consumption during a demand period. If a company's peak demand coincides with a time when the sun is shining, then installing a PV system can reduce their demand, thereby possibly saving them money.

PV can also be an economic boon to a business that needs to power a sign where the grid is inaccessible or it is too expensive to remove asphalt or concrete.

Commercial entities also realize that incorporating some form of renewable energy can be a huge public relations gesture—as well as a way to help with a healthy environment. BP Solar's public awareness campaign with PV visible on their gas stations and educational kiosks at their front doors is a good example of this.

◁ This remote system powers Northern Colorado's Channel 9 news camera used to capture images of Public Service Company of Colorado's wind farm. The self-contained unit serves as a mount for a 900 watt PV array and houses the inverter, batteries, controls, and Channel 9's camera equipment. The hybrid system includes a 6.5kW back-up propane generator. *[Photo courtesy Altair Energy]*

▽ Block Island, Rhode Island, scene of a 6kW ground-mounted system providing grid-connected and back-up emergency power. Block Island was the first post office in the Million Solar Roofs program. Integrator: Solar Works. *[Photo courtesy ASE Americas, Inc.]*

◁ This 6kW grid-connected system at a service station in Olney, Maryland, supplies 15 percent of the station's electrical needs. It is the first to use Solarex's MST43 thin film modules. *[Photo courtesy Atlantic Solar]*

▽ A 120kW array of ASE Americas 300-DG modules was installed by Applied Power Corporation at the Bentley Mills carpet factory in Southern California. APC (Lacey, Washington) also designed the installation, which is one of the largest industrial solar installations in the United States. Bentley Mills is a subsidiary of the Interface Group, a global provider of flooring products with a philosophy of sustainable manufacturing. *[Photo courtesy ASE Americas, Inc.]*

△ This large 20kW system was designed and installed on the Houston Health Science Center by Planergy, Inc. *[Photo courtesy Planergy, Inc.]*

△ Montara Elementary School, first of 165 schools for Los Angeles Unified School District—the largest school district in the U.S.—sports a 4.8 kW school lunch shelter. Solar Utility, Inc. is the exclusive distributor of Uni-Solar's building-integrated roofing material as featured on this school. *[Photo courtesy Solar Utility, Inc.]*

△ The Western Area Power Authority building in Folsom, California, features 12kW Solarex, 12kW EPV, and Trace inverters on its line-tied PV system designed and installed by Solar Electrical Systems, Thousand Oaks, California. *[Photo courtesy Solar Electrical Systems]*

△ Mauna Lani Hotel and Bungalows, Kohala Coast, Hawaii. This unique 100kWp (75kWAC) solar electric tile system is believed to be the largest hotel PV system in the world. PowerLight Corporation, integrator, installed their commercial-scale PowerGuard system using ASE's PV modules, backed with insulating polystyrene foam. The project exemplifies the flexibility of PV—serving as both an electricity generator and a building material. The roof covers 10,000 square feet and is expected to offset more than 14,000 barrels of oil during its life. *[Photos courtesy ASE Americas, Inc. and Sandia National Laboratories (inset)]*

△ An ancient order of Benedictine monks thrives in the modern world. The Monastery of Christ in the Desert is able to pursue a high-tech livelihood—designing web sites—with power brought by Siemens modules. The Brothers use electricity from PV to power 15 computers for web site designs, including the Vatican's web site. Connecting to the nearest electric grid from a remote canyon in northern New Mexico would have cost more than $1 million. The eight solar arrays mounted on trackers follow the sun throughout the day. *[Photo courtesy Siemens Solar Industries]*

▷ By covering the 2,400 square foot lunch eating area at Teofilo Mendoza Elementary School in Imperial Beach, California, with PV (Solar Utility's Uni-Solar panels), shelter is provided and electricity is produced using what would have been otherwise wasted roof space. *[Photo courtesy Solar Utility]*

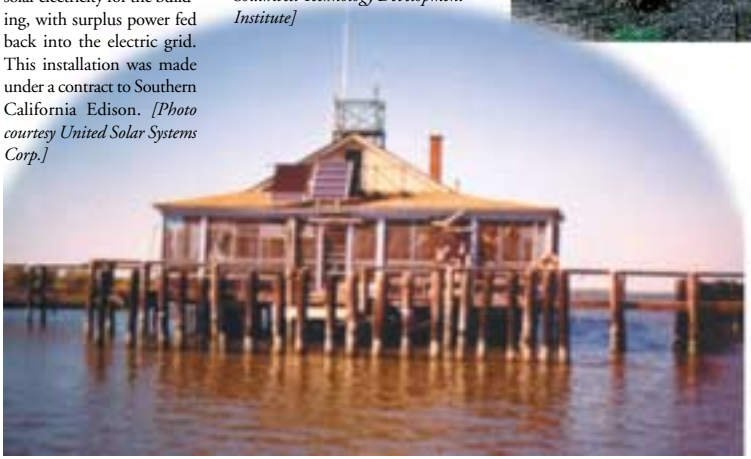
▷ This Rikers Island (New York) facility incorporates BIPV (building integrated photovoltaics). The panels serve as roofing, as skylighting, and as a power source. The Atlantis Energy modules consist of translucent PV designed as multifunctional glazing material. *[Photo courtesy Atlantis Energy]*

△ In partnership with Southern California Edison and the Department of Energy, the Solar Utility team installed a state-of-the-art photovoltaic distributed generation system at the world-renowned Huntington Library, Art Collections and Botanical Gardens. The system provides valuable support to the utility grid during peak load periods. *[Photo courtesy Solar Utility, Inc.]*

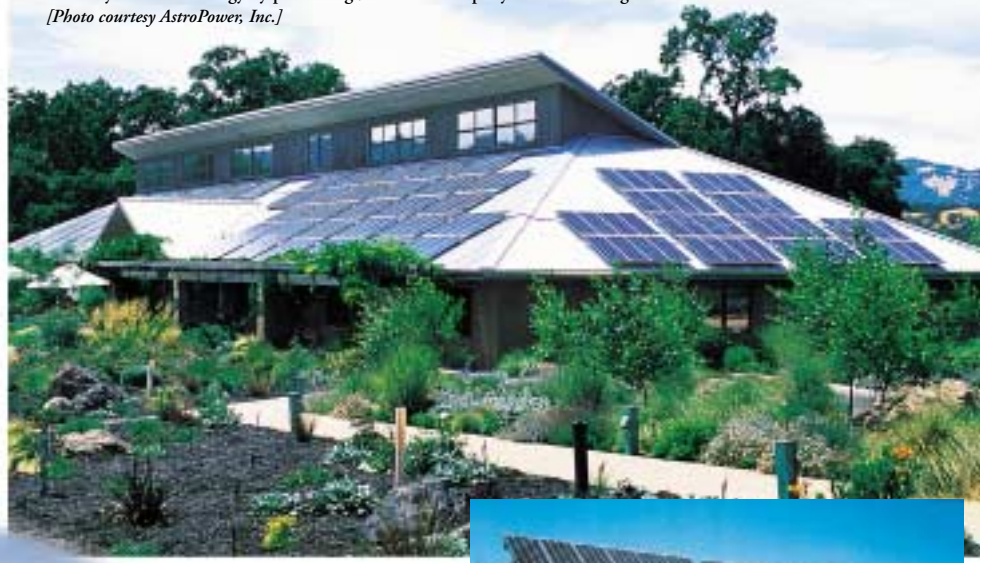
▽ PVI Photovoltaics International's SunFocus Power System™ installation at the Sacramento Municipal Utility District. This 20-panel system, consisting of 240 individual modules, has an output of 31kW of ac power. Each module tracks the sun as it arcs across the sky. The system provides peak load shaving to SMUD and its customers seeking green power. [Photo courtesy of PVI Photovoltaics International]

△ The engineering lab at the University of California, Irvine, uses Uni-Solar structural standing seam roofing panels. The project was performed by Solar Utility Inc. of Culver City, California. The installation provides up to 6kW of grid-connected solar electricity for the building, with surplus power fed back into the electric grid. This installation was made under a contract to Southern California Edison. *[Photo courtesy United Solar Systems Corp.]*

△ The City of Tucson Southeast Service Center (Ward 4) hosts a grid-tied 5kW PV system. With estimated peak daytime electrical loads at about 7kW, this system provides a significant portion of the facility's energy requirements. A data acquisition system designed and installed by the Southwest Technology Development Institute, New Mexico State University, allows remote monitoring of system performance. *[Photo courtesy Southwest Technology Development Institute]*



▽ **This 41.4kW rooftop array on Fetzer Vineyards' administration building in Hopland, Califonia, (shown here and on cover) features AstroPower's AP-106 single-crystal cells, 36 per panel, 90 panels per module, 4 modules. Real Goods Trading Company was the developer/distributor and PowerLight the system integrator. Fetzer plans to run all its operations from electricity generated by renewable energy by purchasing 5 million kWh per year under a long-term contract with Pacific Gas & Electric.** *[Photo courtesy AstroPower, Inc.]*



▷ Bluffsview Elementary School, Columbus, Ohio, a 2kW conventional power system by BP Solar, Inc. *[Photo courtesy BP Solar, Inc.]*

◁ Siemens modules electrify this facility on Fox Island, just on the Virginia side of the Virginia/Maryland line, Chesapeake Bay. The system powers 20-watt flourescent lights, a marine radio, refrigeration, and a wastewater treatment system. Atlantic Solar, Baltimore, Maryland, provided the system for the Chesapeake Bay Foundation. *[Photo courtesy Atlantic Solar]*

The deregulation of the electric utility industry has heralded an increase in grid-tied PV systems on homes, due in part to the fact that consumers now find it easier to own a system that is readily accepted by the utility, and then sell the excess power they create back to the utility. Selling excess electricity generated is the premise of net metering, which several states now allow.

Programs that educate utilities with respect to PV and its successful interface with electric power lines have been increasingly visible. That, too, has promoted the acceptance of PV by utilities, which has often meant incentives offered to consumers, which translates to more utility-tied photovoltaic systems.

It is estimated that there are now at least 20 megawatts of power being generated by grid-tied PV in the United States.

The Million Solar Roofs Initiative has given PV a boost among state energy programs and the general citizenry. Initiatives such as the Sacramento Municipal Utility District's Pioneer program allow residents to purchase SMUD's rooftop systems, which are all net metered, and programs in Florida and Arizona are part of a large thrust to make PV a viable grid-tied option for homeowners.

△ This grid-tied 8.6kW PV system meets all the electric needs of this 4,500 square foot home, including the charger for the family's electric vehicle and an air conditioning system. The system, which was provided by Altair Energy, includes emergency features for covering an electric utility outage, so the family can operate key appliances for a couple of days. These Boulder, Colorado homeowners benefit from net metering. *[Photo courtesy Altair Energy]*

◁ Ascension Technology provided this 2kW array on a grid-connected home in the Minneapolis, Minnesota, area. The project was part of Northern States Power Company's Solar Advantage Program. *[Photo courtesy Ascension Technology]*

◁ Evergreen's EverSun™ ac modules (available through Real Goods Trading Company), provide power for this home. Evergreen Solar is located in Waltham, Massachusetts. *[Photo courtesy Evergreen Solar]*

▽ At a California PVUSA site, this roofing shingle test bed allows more successful residential grid-tied installations throughout the U.S. *[Photo courtesy PVUSA]*

▽ This grid-connected residence was featured in the Denver Home Builders Association's Parade of Homes. The Green Gables home by McStain features a 1.2kW Solarex Solar Energizer® system. *[Photo courtesy Solarex]*

△ This PV system consists of a 1.8 kW array of BP-275 modules, a single Trace SW4048 true sine wave inverter, and 35kWh of battery storage. The system (located in Corrales, New Mexico) is grid connected under a net metering agreement that allows the excess solar energy to be 'stored' on the grid for use when the sun is not shining. *[Photo courtesy Energia Total]*

△ Designed by Solar Design Associates of Harvard, Massachusetts, this home in Kennebunkport, Maine, is approximately 2,900 square feet and produces its own heat, hot water, and electricity from the sun. The south roof incorporates an integrated array of solar thermal collectors and large-area PV modules (4.2kW) to form a single, uniform glass plane. This building-integrated PV is utility-interactive, but could operate as a stand-alone system at any time. The house exports a surplus of power annually via a net metering connection. Modules are by ASE Americas, inverters by Trace, batteries by BP. *[Photo courtesy Solar Design Associates]*

▷ FIRST, Inc., creates homes with a buyer-ready option for choosing a solar power alternative, meaning no retrofit costs. (AvisAmerica was selected by FIRST to supply these factory-built, modular, all-solar homes.) There is every indication that more building-integrated PV will take place, making design and building activities more compatible with PV. *[Photo courtesy FIRST, Inc.]*

▷ Homes with PV included as part of the total purchase price are beginning to be chosen by new home buyers. Two subdivisions that offer such an option are the Reflections at Mace Ranch (Davis, California) and Prodigy Homes (Elk Grove, California), both of which are constructed with Sunslates as upgrades. Sunslates is a product provided by Atlantis Energy of Sacramento. *[Photo courtesy Atlantis Energy]*

△ Bonny Doon, near Santa Cruz, California. Although this home is grid-tied, the location is remote enough that they lose power fairly often during winter storms, making a battery back-up system perfect for them. The array features 24 AstroPower 1106 V modules (1,120W ac), a Trace SW 4048 inverter, and four flooded Trojan batteries. The installation, provided by Pacific Solar Company of Redwood City, California, provides most, but not all, of their electrical needs. *[Photo courtesy Pacific Solar Company]*

△ This solar-shingled home is one of Sacramento Municipal Utility District's customer-owners—part of their PV Pioneers Program—and operates in conjunction with SMUD's solar power plant near Rancho Seco, California. SMUD's PV Pioneer II program offers homeowners the opportunity to purchase rooftop PV units, each of which is net metered. *[Photo courtesy SMUD]*

▽ This roof-mounted 10kW system powers a single residence overlooking the Pacific Ocean. Concorde sealed batteries and two Trace SW5548 inverters accompany 96 AstroPower 1206 modules, designed and installed by Pacific Solar Company. *[Photo courtesy Pacific Solar Company]*

▷ A 2kW grid-tied residential rooftop system in Fairfield, California. *[Photo courtesy BP Solar]*

◁ **This 7,000 square foot Evergreen, Colorado home features a 2.4kW solar electric ground-mounted back-up system. The system supplies about one-fourth of the family's electric needs and provides back-up power to the well pump, heat circulation pump, refrigerator, computer, selected lights, and the security system, in the event of a utility power outage.** ***[Photo courtesy Altair Energy]***

△ Although 20 years passed after Tucson's solar village was first announced, Civano, a planned energy-efficient community, is now a reality. Every Civano home is at least 50 percent more efficient than the model energy code, and nearly a dozen of the 17 model homes built to date have photovoltaic systems on the roofs. *[Photo courtesy Tucson Coalition for Solar]*

◁ The Florida Solar Energy Center and a Lakeland, Florida homebuilder partnered to build and monitor this home, which demonstrates that energy efficient strategies significantly decrease a building's energy load and increase the value of a building's PV system. Photovoltaics, when installed in homes that have already been modified to take advantage of other energy-efficient options, can offset a large percentage of a homeowner's electrical loads. This 4kW PV system over-cools with day time solar energy, avoiding the early evening peak-utility use. *[Photo courtesy Florida Solar Energy Center]*

▽ Some homeowners choose to have their photovoltaic system installed as an awning or patio cover, thereby alleviating the need for a roof-mounted system, while providing a desirable shaded area. *[Photo courtesy Bill Brooks]*

Photovoltaics is very often the preferred power source for residences in remote areas not served by the utility grid.

Why PV on a residence? PV is the logical choice when the cost of having electric lines run to a home is too expensive. PV may also be preferable because the alternative would be a noisy, smelly generator or another power source less reliable than PV.

Increasingly, however, there are instances where the grid is available, but the homeowner simply wants either the independence possible by owning a PV system, or feels strongly enough about environmental issues that the correct choice for that homeowner is some form of renewable energy in lieu of the electric grid.

So-called 'stand alone' PV systems may be roof mounted, pole mounted, or ground mounted, all of which are depicted here. Each has some special design or installation requirements, but each can supply remote residential power quite reliably.

◁ The large remote Navajo Nation in Arizona and New Mexico is the ideal setting for photovoltaic power systems. This home is in the Whitehorse Chapter of the Navajo Nation, where 22 identical systems were installed by AAA Solar. All systems include four Siemens 100W modules on a pole mount, eight Exide E-3600 220 AH deep-cycle batteries, and a Trace DR series 2400W inverter. Enough power is produced for lighting, some small appliances, and a very efficient small refrigerator. *[Photo courtesy AAA Solar]*

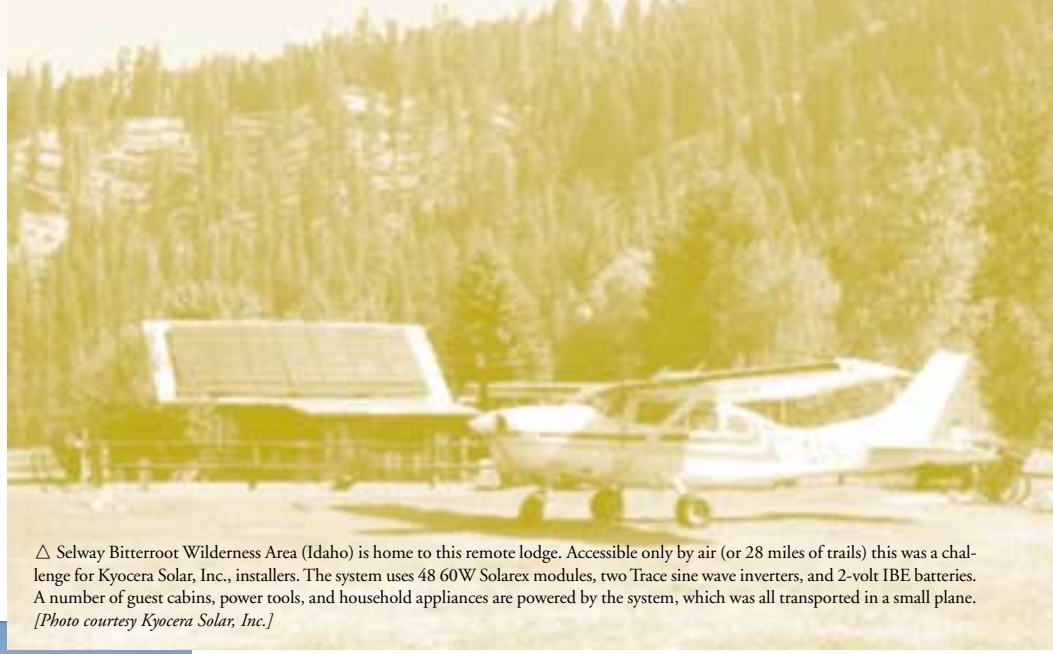
▷ The Willey family, owners of Backwoods Solar Electric Systems, use photovoltaics to power their combination home and solar catalog business. The site is located on an Idaho mountain two miles from utility lines. *[Photo courtesy Backwoods Solar]*

◁ Remote residences are but one place where a photovoltaic unit such as these GenSun solar powered energy systems would prove useful. *[Photo courtesy GenSun Electric Solar Systems, Inc.]*

△ Energia's 600 watt stand-alone FireFly (using BP-275 modules, a Trace sine wave inverter, and Exide batteries) provides electricity to a family living on Pajarito Mesa, a colonia, or unincorporated Hispanic community. While only 5 miles from Albuquerque, New Mexico, about 150 families live without electric service. *[Photo courtesy Energia Total]*

△ PV powers this off-grid 3,000 square foot energy efficient log home near Creston, California. Solar provides primary power with a 15kW generator for backup. Siemens modules, Zomeworks trackers, Trace 4048 inverters, and Trojan batteries are included in the system, which was designed and installed by The Solar Connection, Morro Bay, California. ***[Photo courtesy The Solar Connection]***

△ Ed Begley, Jr., actor and environmentalist, admits his off-grid solar-powered home in the heart of Los Angeles is a sizeable investment, but he wouldn't want to live any other way. His system is comprised of 100 60-watt panels. He has the requisite large battery bank and sinewave inverter in his garage—where he also keeps his PV-charged electric car. *[Photo courtesy Ed Begley, Jr.]*



△ Selway Bitterroot Wilderness Area (Idaho) is home to this remote lodge. Accessible only by air (or 28 miles of trails) this was a challenge for Kyocera Solar, Inc., installers. The system uses 48 60W Solarex modules, two Trace sine wave inverters, and 2-volt IBE batteries. A number of guest cabins, power tools, and household appliances are powered by the system, which was all transported in a small plane. *[Photo courtesy Kyocera Solar, Inc.]*

△ Kyocera Solar, Inc. provided 600W skid-mounted PV systems for 100 homes on the Navajo Reservation. The installations were purchased and installed by the Navajo Tribal Utility Authority (NTUA). *[Photo courtesy Jimmie Daniels, NTUA]*

△ Built partly from recycled steel, this all electric stand-alone home near Prescott, Arizona is powered by a Siemens 11kW system, three Trace inverters and regulators, and Trojan batteries. Part of the PV is ground mounted and part roof mounted. Hitney Solar Products provided all of the panels and components. The large system powers, among other things, a home projection theater, ham radio studio, freezers, and a music studio. *[Photo courtesy Carol Hills, Serenity Studio]*

▽ In the Williamson Valley of Arizona, 18 Siemens Solar panels run along the roof edge (smaller panel is for hot water) of this off-grid home. Designed and installed by EV Solar Products, Chino Valley, Arizona; products provided by Hitney Solar. The installation uses a Trace inverter and Trojan batteries, together providing a 1.35kW array for the residence. *[Photo courtesy EV Solar Products]*

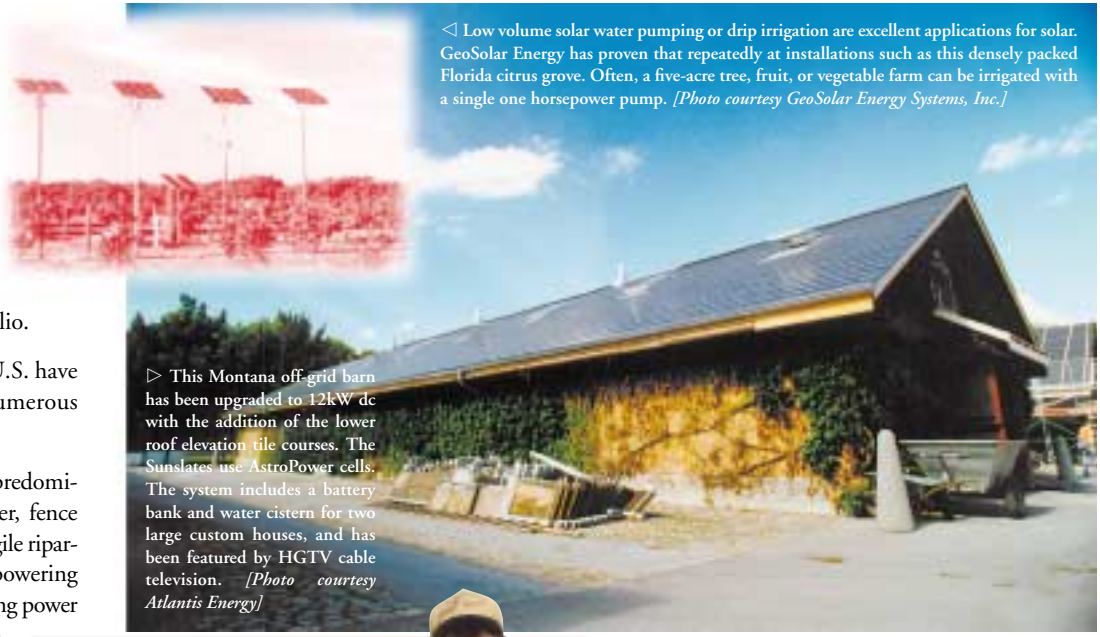
Agricultural applications suitable for PV solutions are numerous. These applications are a mix of individual installations and systems installed by utility companies when they have found that a PV solution is the best solution for a remote agricultural need such as water pumping for livestock or crops. Everyone wins when utilities provide PV services as part of their overall service portfolio.

More than one hundred utilities in the U.S. have integrated PV-powered systems for numerous applications within their service area.

Photovoltaics in agricultural settings is predominantly used for water pumping. However, fence electrification, particularly for isolating fragile riparian areas, is a growing use, as is PV for powering remote farm and ranch homes and providing power for the labor-saving tools necessary to run a modern operation. Other agricultural uses run to fly control with PV-powered sprayers, PV for a fish farming compressor to aid with pond aeration, or PV-provided electricity for poultry cooling fans.

In short, farmers and ranchers often choose PV because it saves money. Utilities, likewise, offer PV services because it saves money.

As with any use of PV, the agricultural applications are limited only by one's imagination.



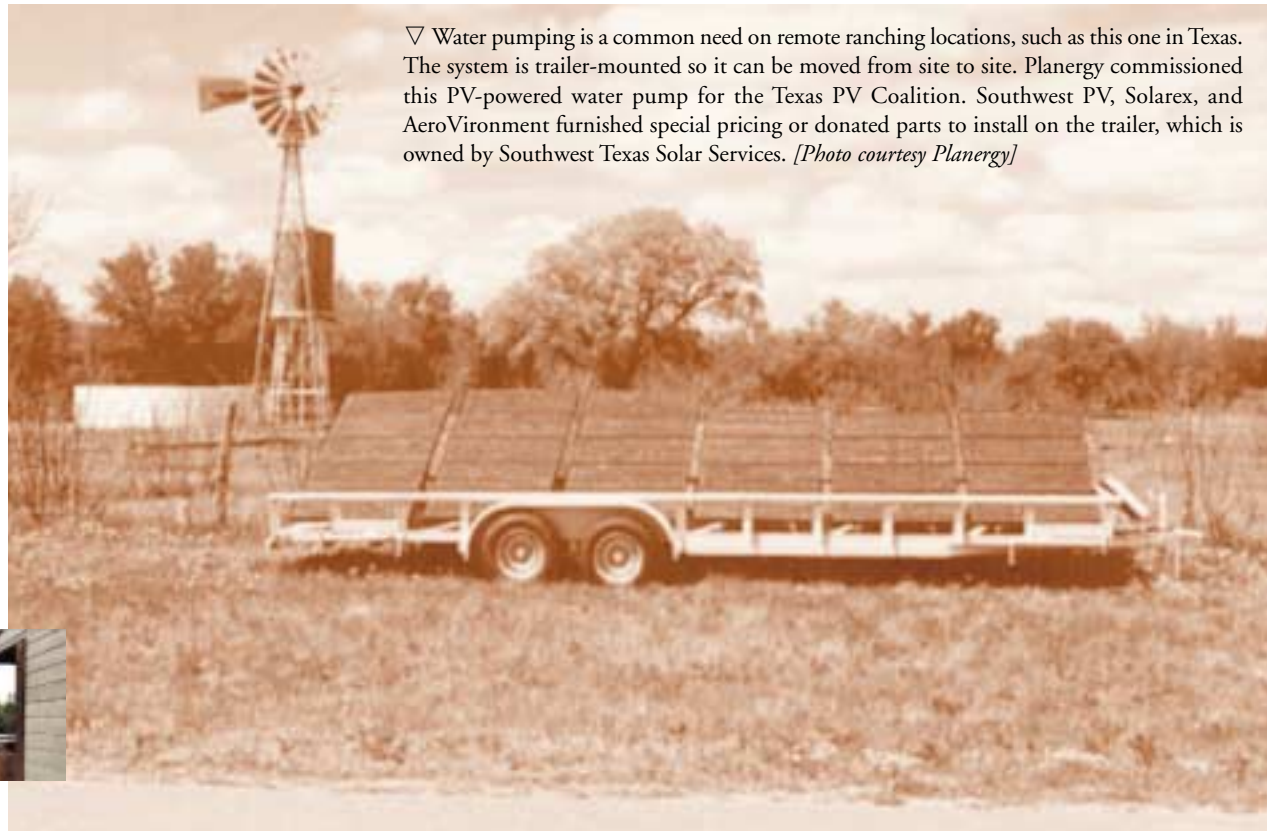
◁ Low volume solar water pumping or drip irrigation are excellent applications for solar. GeoSolar Energy has proven that repeatedly at installations such as this densely packed Florida citrus grove. Often, a five-acre tree, fruit, or vegetable farm can be irrigated with a single one horsepower pump. *[Photo courtesy GeoSolar Energy Systems, Inc.]*

▷ This Montana off-grid barn has been upgraded to 12kW dc with the addition of the lower roof elevation tile courses. The Sunslates use AstroPower cells. The system includes a battery bank and water cistern for two large custom houses, and has been featured by HGTV cable television. *[Photo courtesy Atlantis Energy]*

▷ Cattle aren't the only customers for water provided through PV-powered systems. Here, a herd of American bison roam the Great Plains in Nebraska, with the help of a SunRise® sealed-piston submersible pump made available through Dankoff Solar, Santa Fe, New Mexico, designers of the 300 watt installation. Siemens Solar modules were used, with the array mounted on Zomeworks Track Rack®. The installation was made by Northwest Rural Public Power, Hay Springs, Nebraska. *[Photo courtesy Dankoff Solar Products]*

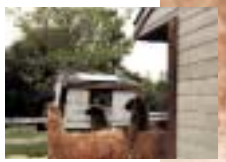
◁ Parker McCrory, Kansas City, Missouri is one of the largest buyers of PV panels in the United States. The company's 6-volt solar powered fencer is sold in huge volume to electrify more than one hundred thousand miles of fences for agricultural purposes in the U.S. Solarex modules are used in all ParMak's solar fencing products, which are custom-manufactured at Solarex' facility. *[Photo courtesy Parker McCrory]*

△ SunWize Technologies introduced the first commercial, completely automatic solar electric ice making plant in Chorreras, Chihuahua, Mexico, to benefit a fishing cooperative of about 70 families. Previously, the coop depended on buyers traveling from Chihuahua to purchase and transport their catch, since they had no refrigeration capabilities of their own. The Planta de Hielo SunWize has brought economic independence to the cooperative. *[Photo courtesy SunWize Technologies, Inc., a Besicorp Ltd. Company]*



▽ Water pumping is a common need on remote ranching locations, such as this one in Texas. The system is trailer-mounted so it can be moved from site to site. Planergy commissioned this PV-powered water pump for the Texas PV Coalition. Southwest PV, Solarex, and AeroVironment furnished special pricing or donated parts to install on the trailer, which is owned by Southwest Texas Solar Services. *[Photo courtesy Planergy]*

▷ A Pennsylvania llama farm benefits from photovoltaics. In the summertime the animals love sitting in front of fans. Costs would have been prohibitive to electrify each of the llama 'condos' by any means other than PV, so each home has been fitted with 300 watts of solar electricity (four 75-watt AstroPower panels each). *[Photo courtesy Atlantic Solar]*



▽ Currin Corporation, Midland, Michigan, designed and installed this 900 watt PV array at the Hickory Ridge Farm in Chelsa, Michigan. The system is a hybrid, with diesel generator, wind, and utility power sources in addition to the PV, all powering a farm home and shop. The system includes ten Siemens Solar SR-90 PV modules, a 14 kWh 24-volt bank of Concorde sealed AGM batteries, and a Trace 4.0 kVA sinewave inverter. *[Photo courtesy Currin Corporation]*

▷ Ranching operations could benefit from a PV-powered gate opener, such as this one installed at Maroon Lake near Aspen, Colorado, in the White River National Forest. *[Photo courtesy Sandia National Laboratories]*

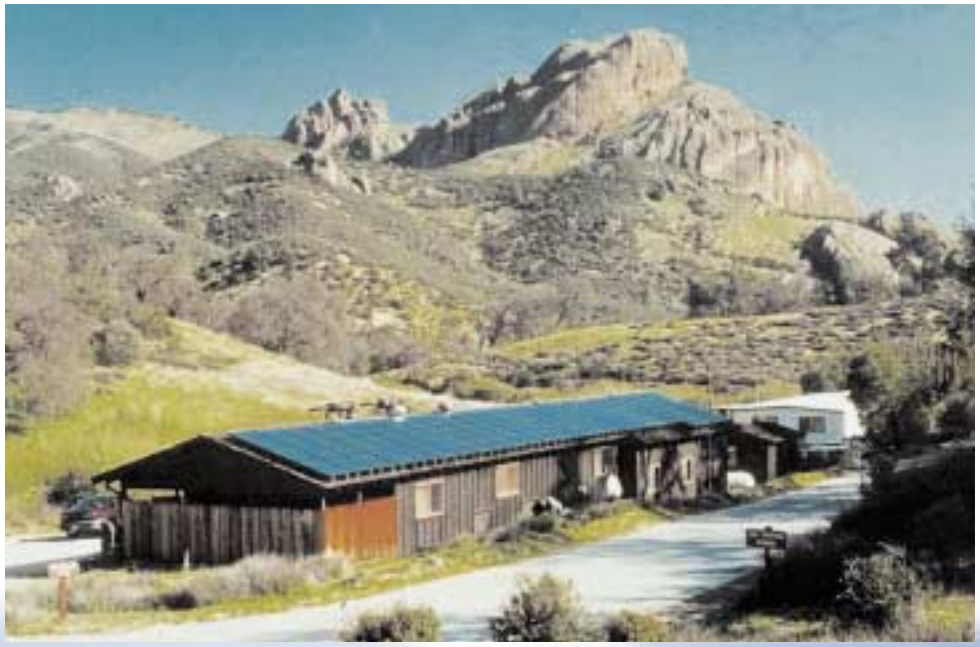
Facility power means different things to different people. For purposes of *Power Where You Need It,* we use the term in a pure sense: power for a facility or a building.

Sandia National Laboratories has a long history of assisting the federal government with renewables. Its Renew series has featured more than one hundred such installations, no small number of which were PV power for a facility. The facility may have been a restroom, a camp headquarters, or a ranger station.

Likewise, facility power can range from a few watts to ten kilowatts, or larger.

Photovoltaics offers government agencies the ability to replace noisy or polluting generators with clean, quiet power.

Facility power within the federal agencies such as the National Park Service, the USDA Forest Service, and the Bureau of Land Management can only continue to grow because an increasingly informed public will demand that pristine sites be protected and clean power be used to provide improved recreational services.



△ One of the most successful photovoltaic facility power installations has been the one at Chaparral, Pinnacles National Monument, California, for the National Park Service. A 10kW roof-mounted array (Solarex modules) provides facility power to park residences, a ranger contact station, a maintenance building, and a campground. The hybrid system (installed by Applied Power Corporation) includes a 20kW propane generator and totally eliminates the use and storage of diesel fuel in the Chaparral area. *[Photo courtesy Sandia National Laboratories]*

△ This installation at Salinas Pueblo Missions National Monument, New Mexico, is somewhat different from the other systems shown here. Salinas is grid-connected and the system shown supplies the needs of the building during much of the year and powers an Uninterruptible Power Supply to handle critical security should the power fail. Springer Electric Cooperative supplied the system, which was installed by Direct Power and Water, Albuquerque. The array uses Solarex modules, Deka valve-regulated batteries, and a Trace inverter. *[Photo courtesy Sandia National Laboratories]*

▽ A 21kW stand-alone PV system (Siemens modules) with battery storage, a Trace inverter, and a 30kW propane back-up generator, were provided for Joshua Tree National Park near Palm Springs, California, for the National Park Service, by Southern California Edison and Kyocera Solar, Inc. Park Service personnel say the award-winning system has cut their operating costs by 90 percent and reduced tons of pollutant emissions, from two diesel generators that the system replaced. Depicted are the main system and *(insert)* the Cottonwood system. *[Photos courtesy Sandia National Laboratories]*

△ This large scale (5kW+) central power station provides all the power required for this island located in the U.S. near the Gulf of Mexico. The system contains 120kW hours of storage using sealed, maintenance-free batteries, to provide power to four homes and a marina. The system was provided by Solar Electric Power Company, Ltd. (SEPCO), Stuart, Florida. *[Photo courtesy SEPCO™]*

△ A small PowerPod sits atop a bathroom facility at Rifle Gap State Park, installed for the Colorado State Parks by Sundance Solar. The PowerPod P-150/250-12 is powering lighting and an exhaust fan. *[Photo courtesy PowerPod Corporation]*

△ Hole in the Wall trail maintenance facility, Sequoia National Park, California. The 8kW hybrid system was supplied by BP Solar and provides power to a remote trail-maintenance facility. *[Photo courtesy BP Solar, Inc.]*

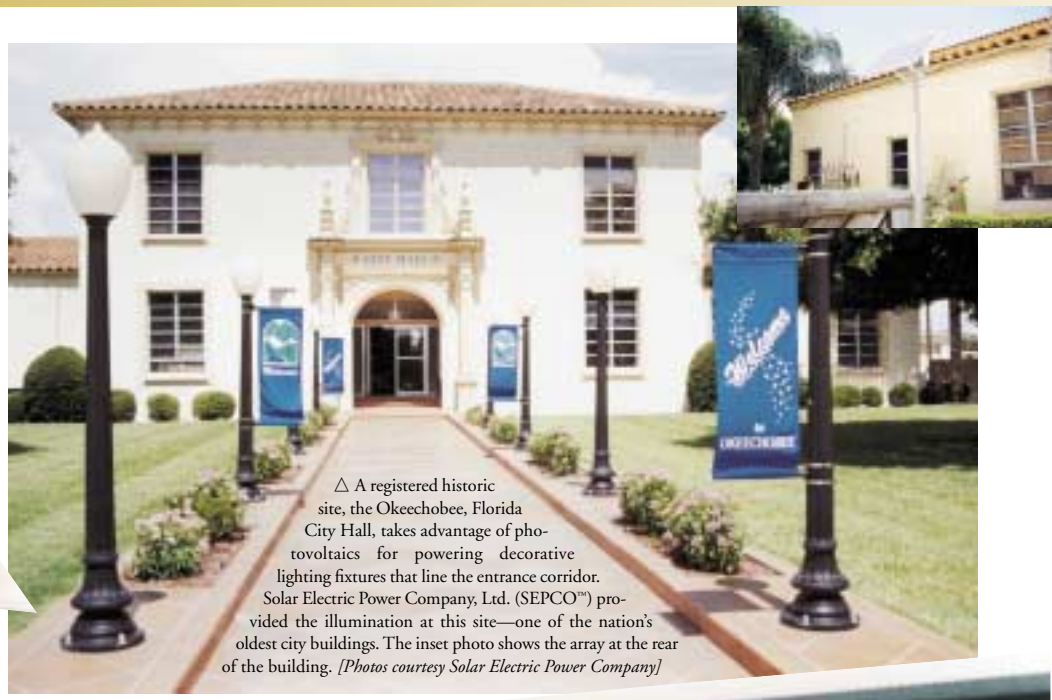
In many cases PV systems can provide light for a fraction of what it would cost to extend a utility line. Indeed, PV systems are powering lights around the world.

The most efficient systems use fluorescent lamps, but other types of lamps, such as halogen or low-pressure sodium, have also been used in conjunction with PV. Batteries are always a component of PV-powered lighting systems, so that power is created when the sun shines, stored in the battery, and enjoyed when the sun has ceased to shine.

If a homeowner decides that a single pole-mounted security light fits the bill for a dark corner of his property—and an electric line is nowhere around—then PV is the perfect solution.

But illumination for its own sake isn't the whole story. Studies show that lights in developing countries mean a longer, more productive work day and a community drawn closer together.

Pre-packaged systems at affordable prices from numerous dealers means no one need remain in the dark.



△ A registered historic site, the Okeechobee, Florida City Hall, takes advantage of photovoltaics for powering decorative lighting fixtures that line the entrance corridor. Solar Electric Power Company, Ltd. (SEPCO™) provided the illumination at this site—one of the nation's oldest city buildings. The inset photo shows the array at the rear of the building. *[Photos courtesy Solar Electric Power Company]*

◁ SEPCO's photovoltaic lighting system at the Greater Orlando International Airport was selected as PV Project of the Year in 1998. The lights are installed throughout the airport grounds: in the employee parking lot, at security entrance checkpoints, and at transit shelters. *[Photo courtesy Solar Electric Power Company, Ltd. – SEPCO]*

▷ Uni-Kit solar lighting systems is but one of the many available to provide electric lights in remote areas around the world. In developing countries, small PV systems that provide enough power for lights is a common application. Here, a young woman in Chiapas, Mexico carries the system up a mountain road leading to her village. *[Photo courtesy United Solar Systems Corp.]*

△ The City of Cocoa Beach, Florida, is lighted with Solar Electric Power Company systems. The City uses PV lighting for their entrance signs, which power energy-efficient neon tubes for dazzling brightness. *[Photo courtesy Solar Electric Power Company, Ltd .– SEPCO]*

◁ The North Carolina Department of Transportation uses PV-powered lighting at its park and ride lot in Raleigh. This is a fairly common and truly appropriate use of photovoltaics. *[Photo courtesy North Carolina Solar Center]*

▽ Solar Outdoor Lighting provides a solar powered Rural Area Light (shown here) that has been used many times to light livestock pens, barns, or any other 'dark' areas at ranching and farming locations. This particular system is designed to operate five consecutive nights without sunlight. Panels are by Solarex. *[Photo courtesy Solar Outdoor Lighting]*

▽ A large GSA parking facility outside the federal building and court house in Puerto Rico, takes advantage of two 64W PV arrays for lighting. The installation, provided by Solar Outdoor Lighting, Inc., is a combination of single and double fixtures, using a total of 23 lights to cover an area approximately 980 by 640 feet. *[Photo courtesy Solar Outdoor Lighting, Inc.]*

◁ Solar lighting provides security at the entrance to Pittman Work Center, Ocala National Forest, Seminole Ranger District, Florida. The Model PM 150 features a dome-style Cobrahead fixture and is installed on a fiberglass pole. The light was provided by Solar Outdoor Lighting, Stuart, Florida. *[Photo courtesy Solar Outdoor Lighting]*

◁ Perimeter security lighting is essential at the NASA Kennedy Space Center tracking station, operated by Allied Signal. A total of 39 lights are in service. *[Photo courtesy Solar Outdoor Lighting]*

◁ A one-room school house in Maryland hosts PV to power a security system used to protect this historic treasure. The system is a 166 watt Solarex array. *[Photo courtesy Atlantic Solar Products]*

▷ Solar parking lot lights are installed along the east side of the bachelor officers' quarters at the Marine Corps Air Station, Yuma, Arizona. Solar Outdoor Lighting provided the lights, which are not grid connected. They are 150W flourescent-type fixtures with reflectors. *[Photo courtesy U. S. Marine Corps]*

▷ While waiting for the bus, riders can feel more secure with the lighting that PV provides. In many instances, it is more cost effective for PV to be used in these isolated situations than it would be to run power from the grid. Shown here is one of several systems provided in Houston, Texas. *[Photo courtesy SEPCO]*

△ **Yuma Proving Ground uses small PV arrays to provide security lights at vital locations.** ***[Photo courtesy U.S. Army]***

◁ **An 18 watt Solarex panel provides power for a parking lot security system and light.** ***[Photo courtesy Atlantic Solar Products]***

▽ **Photovoltaics provided an ideal solution for Wendy's, Atlanta, Georgia. The restaurant needed lights for safety reasons behind their facility. Although the utility grid was close by, tying to the grid would have proven much more expensive than installing the PV-powered lights.** ***[Photo courtesy Sandia National Laboratories]***

▷ Police departments across the U.S. appreciate lighted lots—and often PV is the power of choice for such applications. These Double PowerFlood Systems were provided by SEPCO. Security is better ensured when law enforcement officers can quickly see entire lots without having to drive the area. *[Photo courtesy SEPCO™ – Solar Electric Power Company, Ltd.]*

The whole sphere of transportation is ripe for photovoltaics. Indeed, railroads depend heavily on PV as a power source for control and safety in rail yards and elsewhere. Often this use is a function of economics, but often reliability is the rail industry's primary concern. And photovoltaics is nothing if not reliable.

Batteries are an integral part of many forms of transportation. But batteries have an inherent problem in that they self-discharge over time if they are not being used. To overcome this problem, the Detroit area national guard—which meets only every two weeks—has installed PV-powered trickle charge units to keep their batteries at a high state of charge.

Solar electric cars (charged with a PV system that sometimes also powers a residence or business) are an option appreciated by motorists whose daily needs can accommodate fairly short mileage.

Included in these photographs are various forms of highway transport, but also some useful 'aids to transport' which—with PV—help ensure our safety in an attractively economical trade-off.

◁ This ground-mounted PV system serves as an electric refueling station for the Presidio National Park's electric vehicles. The system is also line-tied, so excess electricity is fed back to the utility. The refueling station is located in front of the Thoreau Center for Sustainability at the San Francisco park. *[Photo courtesy Altair Energy]*

▷ PV-lit highway signs such as this one constructed for the Florida Turnpike's District Traffic Operations, are commonly seen on the nation's highways. This application is particularly well suited to photovoltaics, because the cost of running traditional electric service under the road would be prohibitive. *[Photo courtesy Solar Outdoor Lighting]*

▽ When an over-height vehicle is on course to hit an upcoming bridge, a solar-powered detection system sets off several warning devices, including a large neon-lighted sign, two powerful arrow warning flashers, a bright flashing strobe light, and a large klaxon. This installation is for the New York Department of Transportation, provided by SEPCO™. The 200W system has a piggy-back box containing an inverter, which sends ac voltage 1500 feet down the highway to power the warning devices. *[Photos courtesy Solar Electric Power Company, Ltd. – SEPCO]*

▽ Portable units such as this one for speed control have long been a great application for photovoltaics. *[Photo courtesy Sandia National Laboratories]*

△ Powered in part by PV, this vehicle demonstrates energy-efficient and environmentally sound public transportation. The PV array on the roof provides about one-fourth of the bus' daily power requirement. It runs at a top speed of 24 miles per hour. *[Photo courtesy Foster and Partners, Richard Davies, photographer]*

◁ A solar electric car that can travel 55 miles suits actor Ed Begley, Jr. just fine. His PV system fully electrifies his home and provides electricity for his converted Volkswagen Rabbit. According to the U.S. Department of Transportation, most trips taken by Americans are 40 miles or less. *[Photo courtesy Ed Begley, Jr.]*

△ Here a 10 watt Solarex solar array helps with roadway safety. *[Photo courtesy Atlantic Solar Products]*

△ Twelve Solarex 60W modules power railroad signaling equipment in Western Montana. This type of remote application is a very common use of photovoltaics. *[Photo courtesy Kyocera Solar, Inc.]*

▷ Fresh fruits and vegetables are delivered to stores in the South East region of London in a solar-powered, refrigerated lorry. The unit, powered by PV panels on the vehicle's roof, was developed by Sainsbury's Supermarkets (Britain's oldest major food retailing chain) in partnership with academic and commercial interests, to look at the potential for renewable energy in this application. After a couple of years' use, all reports indicate that the lorry serves this unique application quite well. *[Photo courtesy Sainsbury's]*

△ The Virginia Department of Transportation uses photovoltaics to power their weigh-motion stations. Among other functions, this equipment sets the speed of traffic. This traffic monitoring station is powered by a 1,280 watt solar array. *[Photo courtesy Atlantic Solar]*

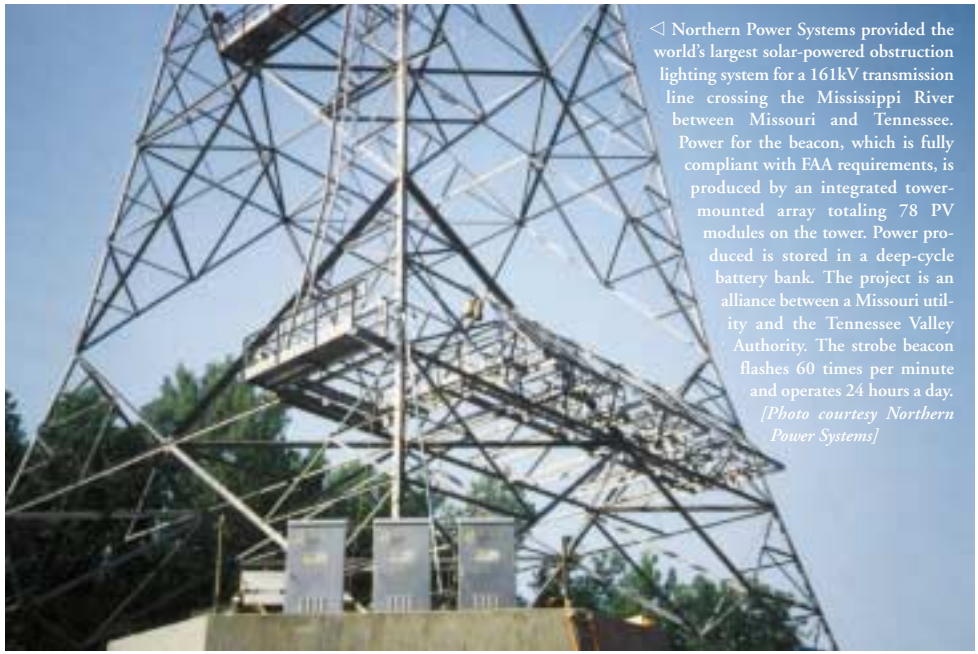
▽ North Carolina State University at Raleigh has a 1.6kW PV charging station. Here, one of its fleet, an S-10 electric truck. *[Photo courtesy North Carolina Solar Center]*

Along America's waterways, one of the earliest terrestrial uses of PV are navigational buoys and other aids to navigation. The loads required for these applications are typically small, the installations are remote, and the utility grid is not generally accessible, making PV a perfect match for this use.

Applications may range from lighthouse beacon power to a small single-module system posted on a lonely stretch of riverbank. But because these signals, sirens, and lights are all lifesaving measures, system reliability is paramount. PV provides that critical reliability.

The United States Coast Guard has converted all its navigational buoys from primary batteries to PV-powered rechargeable batteries, thus saving millions of dollars in battery replacement costs alone.

In fact, warning signs, signals and lights—typically navigational beacons—are one of the most popular applications for PV in the United States.



◁ Northern Power Systems provided the world's largest solar-powered obstruction lighting system for a 161kV transmission line crossing the Mississippi River between Missouri and Tennessee. Power for the beacon, which is fully compliant with FAA requirements, is produced by an integrated tower-mounted array totaling 78 PV modules on the tower. Power produced is stored in a deep-cycle battery bank. The project is an alliance between a Missouri utility and the Tennessee Valley Authority. The strobe beacon flashes 60 times per minute and operates 24 hours a day. *[Photo courtesy Northern Power Systems]*

◁ The U. S. Coast Guard has converted all its navigational buoys from primary batteries to PV-powered rechargeable batteries and is saving millions of dollars a year on the cost of servicing and maintaining them. This single-module system is typical of more than 14,000 sites that the U.S. Coast Guard has converted. The module is covered to protect against vandalism. *[Photo courtesy Sandia National Laboratories]*

▷ A 100W Solar Electric Power assembly operates a digital camera monitoring system, which scans a major waterway for marine traffic. The system operation and location are confidential, but this type of high security system is growing popular for many applications. Similar systems operate recording devices, power alarms, and power remote video surveillance systems, to name just a few security-type applications. *[Photo courtesy SEPCO™ – Solar Electric Power Company, Ltd.]*

◁ Photovoltaics powers the navigational light at the Bureau of Land Management's Turn Point Light Station, Stuart Island, San Juan Islands, Washington. *[Photo courtesy Sandia National Laboratories]*

◁ A 650 watt AstroPower array powers a flashing light in the Fenwick Island Lighthouse located on the Delaware-Maryland line. *[Photo courtesy Atlantic Solar Products]*

▽ A large pole-mounted stand alone power assembly illuminates 18 decorative fixtures and a lighthouse for the Kisimee (Florida) Parks and Recreation Department. At the end of the peninsula, the small-scale lighthouse flashes at the rate of a large-scale lighthouse with white LED lights. *[Photo courtesy Solar Electric Power Company, Ltd. – SEPCO]*

△ This small PV installation at the dock at Stuart Island, San Juan Islands, Washington, is sufficient to power an effluent dump station for boats that dock there. *[Photo courtesy Sandia National Laboratories]*

◁ Aids to navigation are some of the most popular uses for photovoltaics. Pictured here is a PV array for the Au Sable Light Station complex. The highest subarray, with the horizontal bar above it, is designed to always be above the snow level so that some solar power will be available throughout the winter. Snowfalls at the area have reached 70 inches. The horizontal bar is for protection from falling trees. The inset photo is the quaint lighthouse at Au Sable, Michigan, a registered historic site. The system was designed and installed by Currin Corporation, Midland, Michigan. *[Photos courtesy Currin Corporation and Sandia National Laboratories]*

Elsewhere in *Power Where You Need It* we have featured dozens of applications where photovoltaics plays a part—or takes the lead—when it comes to our national infrastructure. Webster defines infrastructure as an "underlying foundation or basic framework." Here, infrastructure is meant to include all the many fundamental, vital ways in which we are inter-connected: Our means of travel (roads, waterways, and railways); our means of power (our electric grid); and our telecommunications systems.

Shown here are examples of other components of a basic national infrastructure: satellites, telephones, cable television, subway transportation, oil and gas pipelines, and water systems.

Photovoltaics has even played a part in our airways: in Antarctica, PV-powered runway lights have been used.

△ A 1997 Mars Pathfinder satellite, one of several NASA explorations of the Red Planet. *[Rendition courtesy National Aeronautics and Space Administration]*

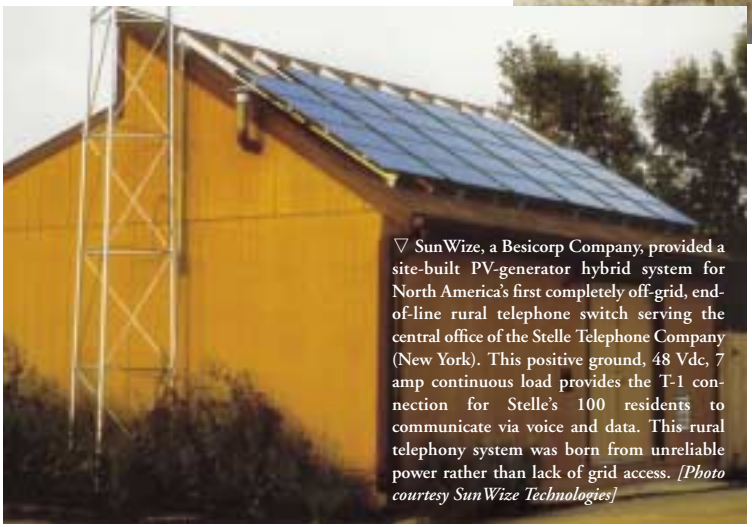
◁ Photovoltaic power for remote applications is a superior use of the technology. Here a Hutton Power Systems 48-watt Sun-Tel cellular data unit powers a water pipe flow monitor in the Houston area. Water utilities throughout the country use similar systems. *[Photo courtesy Hutton Communications]*

△ Washington Metro Subway System makes excellent use of PV to power indicator lights for their trains. Since most of the system's trains are underground, it was difficult for bus drivers to know when trains were approaching. Passenger complaints at missing their connections have greatly diminished, as the bus drivers now see the flash of lights signaling an approaching subway train. The system uses Solarex panels. *[Photos courtesy Atlantic Solar Products]*

▽ On a lonely stretch of beach between two Florida cities, a cable TV operator discovers greatly increased customer service through the use of solar energy. This system is powered by a 900W SEPCO system, which contains 21kWhs of sealed Gel battery storage located at the far side of the array. *[Photo courtesy Solar Electric Power Company – SEPCO]*

▷ An emergency call box is a common use for a small photovoltaics panel. *[Photo courtesy Kyocera, Inc.]*

▽ About 15 miles south of Fairbanks, Alaska, a small PV panel (and a solar thermal panel) prove perfect for one of PV's more diverse applications. An antifreeze solution is pumped through tubing to a culvert, where it keeps the culvert warm enough to thaw the water so it can run under the highway. Otherwise, that same water would run over the highway, creating treacherously icy conditions. This principle could be used to thaw rain gutters and the like. *[Photo courtesy Sandia National Laboratories]*



▽ SunWize, a Besicorp Company, provided a site-built PV-generator hybrid system for North America's first completely off-grid, end-of-line rural telephone switch serving the central office of the Stelle Telephone Company (New York). This positive ground, 48 Vdc, 7 amp continuous load provides the T-1 connection for Stelle's 100 residents to communicate via voice and data. This rural telephony system was born from unreliable power rather than lack of grid access. *[Photo courtesy SunWize Technologies]*

△ A Hutton Communications installation for a natural gas utility provides flow monitoring for oil pipelines and wells in Oklahoma and elsewhere. This type of remote telemetry is an ideal application for photovoltaics. *[Photo courtesy Hutton Communications]*

▷ A Siemens panel provides power for a public telephone where there would otherwise be none. This type of application is an excellent match for PV whether in a foreign country or in the United States. *[Photo courtesy Siemens Solar]*

When considered on a worldwide basis, telecommunications provides the lion's share of market opportunities for photovoltaics. Even in the U.S., there is a very large market for telecommunications both in the private sector and among military and government agencies.

Telecommunications applications range from small emergency call boxes to large microwave repeaters, and everything in between. The list of telecom applications grows continuously: relay towers, radio systems, remotely controlled systems, and cellular telephones, to name just a few. These systems range from a few watts to several kilowatts. PV is ideal for communications because the PV-charged battery provides a stable dc voltage and meets varying current demands. PV systems operate reliably—and with little maintenance.

There are thousands of telecommunications systems in use powered either by PV alone or powered by PV in conjunction with another fuel source, such as diesel. These systems, without fail, have proven that PV can increase the reliability and spatial coverage of telecommunications systems of all types.

◁ A solar-powered remote telemetry system provided by Solar Depot, San Rafael, California. This is a common application for photovoltaics. *[Photo courtesy Solar Depot]*

◁ A solar-powered cellular link. *[Photo courtesy Solar Depot]*

◁ Northern Power supplied this TeleSol™ PV stand-alone system to Cubic Corporation for a U.S. Air Force Tactical Air Combat Maneuvering and Instrumentation Range located on Nellis Air Force Base outside Las Vegas, Nevada. The sole power source is a 440W solar array comprised of 8 SM55 PV modules supplied by Siemens Solar. Energy produced, if not immediately consumed by the load, is stored in Deka Unigy II series batteries manufactured by East Penn of Lyons, Pennsylvania for this project. The 'brains' of the system is a Northern SC-50 controller. *[Photo courtesy Northern Power Systems]*

△ Northern Power Systems designed, manufactured, and installed a hybrid MicroGrid™ PV/diesel system on a 10,200′ mountaintop site (Mt. Callaghan) in Central Nevada. The system serves as a master site for the Top Gun Tactical Air Combat Training System upgrade on the U.S. Navy's Fallon Range. The power system consists of an 11,872-peak watt PV array coupled with a 20kW diesel generator set. *[Photo courtesy Northern Power Systems]*

◁ Solar Depot installed this solar-powered pair-gain system. This application is well suited to PV. The twisted pairs of wire, stretching far enough that they lose their signal, benefit from the addition of a PV-powered amplifier. *[Photo courtesy Solar Depot]*

◁ Cellular repeaters are often very large or for other reasons are not always good candidates for photovoltaics. This installation by Solar Depot, however, serves an appropriate application of PV for this purpose. *[Photo courtesy Solar Depot]*

◁ A state-of-the-art communications repeater was installed on Mt. Washington, part of the Manzano Mountains, Albuquerque, New Mexico. A 1750 watt array was mounted on an existing communications tower. The engine generator and a communications building are part of the background. This installation serves as a remote communications link for Kirtland Air Force Base personnel and Department of Energy security guards, as well as for Sandia National Laboratories personnel. It is the only communications in place for military personnel performing field exercises in the area. Direct Power and Water, Albuquerque, performed the design and installation. *[Photos courtesy Sandia National Laboratories]*

There are virtually thousands of reasonable and logical ways for utility companies to use photovoltaics, all of which have an immediate payback—all of which prove that PV can be a less expensive option than conventional service.

Many utility companies are using PV for their isolated, low energy, or low-revenue loads that are costly to operate via conventional means. PV can provide service to low-revenue loads where line extensions would be unfeasible.

Communications, warning signals, sectionalizing switches, cathodic protection, lighting, monitoring, and battery charging head up a growing list of appropriate applications for PV within utilities. Others include automated gas meters and gas-flow computers, gas samplers, and the like.

Participation across the U.S. by utility companies is still rather uneven. There are utilities that have determined that PV is their most reasonable option for many small loads—and there are utilities that have not yet made the decision to include photovoltaics among their options.

From a few watts to several kilowatts—the opportunities for utility incorporation of PV are wide open.

◁ BJ's Wholesalers in North Dartmouth, Massachusetts, serves as host to Sun Power Electric's first power plant. Following utility deregulation in Massachusetts, environmentally conscious electricity consumers' needs are being met through this 'green electric' product. There are actually three PV systems on BJ's. Two are wall mounted and one is roof mounted using special clips on a standing seam roof. The PV consists of 4 SunSine AC modules from Ascension Technology, 4 Evergreen Solar AC modules, and a 12kW ASE Americas system. *[Photo courtesy ASE Americas]*

▽ The City of Alameda (California) Bureau of Electricity commissioned this roof array on a parking structure at the Alameda Boat Harbor. The array consists of 78 Solarex 64W modules, grid-tied, using Trace Engineering's SW4048 UT inverter. The installation was performed by Pacific Solar Company, Redwood City, California, and partially funded by UPVG. *[Photo courtesy Pacific Solar]*

▽ This PV array field at Davis, California is operated by PVUSA, providing a ready test bed for utility applications. *[Photo courtesy PVUSA]*

▷ Here photovoltaics is used to operate a strobe light for Alabama Power. The installation was done by Hutton Communications. *[Photo courtesy Hutton]*

◁ Even though there is clearly conventional power available at this sectionalizing switch on Public Service Company of New Mexico's transmission line, the cost of transformers, surge arrestors, switches, and a rectifier to make the dc required for switch operation was greater than the cost of PV. The application requires only minimal annual energy, so this particular application is an ideal match for a small PV system. *[Photo courtesy Sandia National Laboratories]*

△ Remote telemetry for monitoring oil, gas and water pipelines is a common application for photovoltaics. Kyocera Solar, Inc. installed this monitoring system. *[Photo courtesy Kyocera Solar, Inc.]*

◁ PV powers this utility translator for Salish Kootenai Community College. The installation is on Pistol Creek Look Out, Idaho, and consists of 24 Solarex MSX 64W modules, delivering 1563kW output in peak sun. Storage is in 12 IBE industrial batteries; charge regulators are SCI PPC. *[Photo courtesy Kyocera Solar, Inc.]*

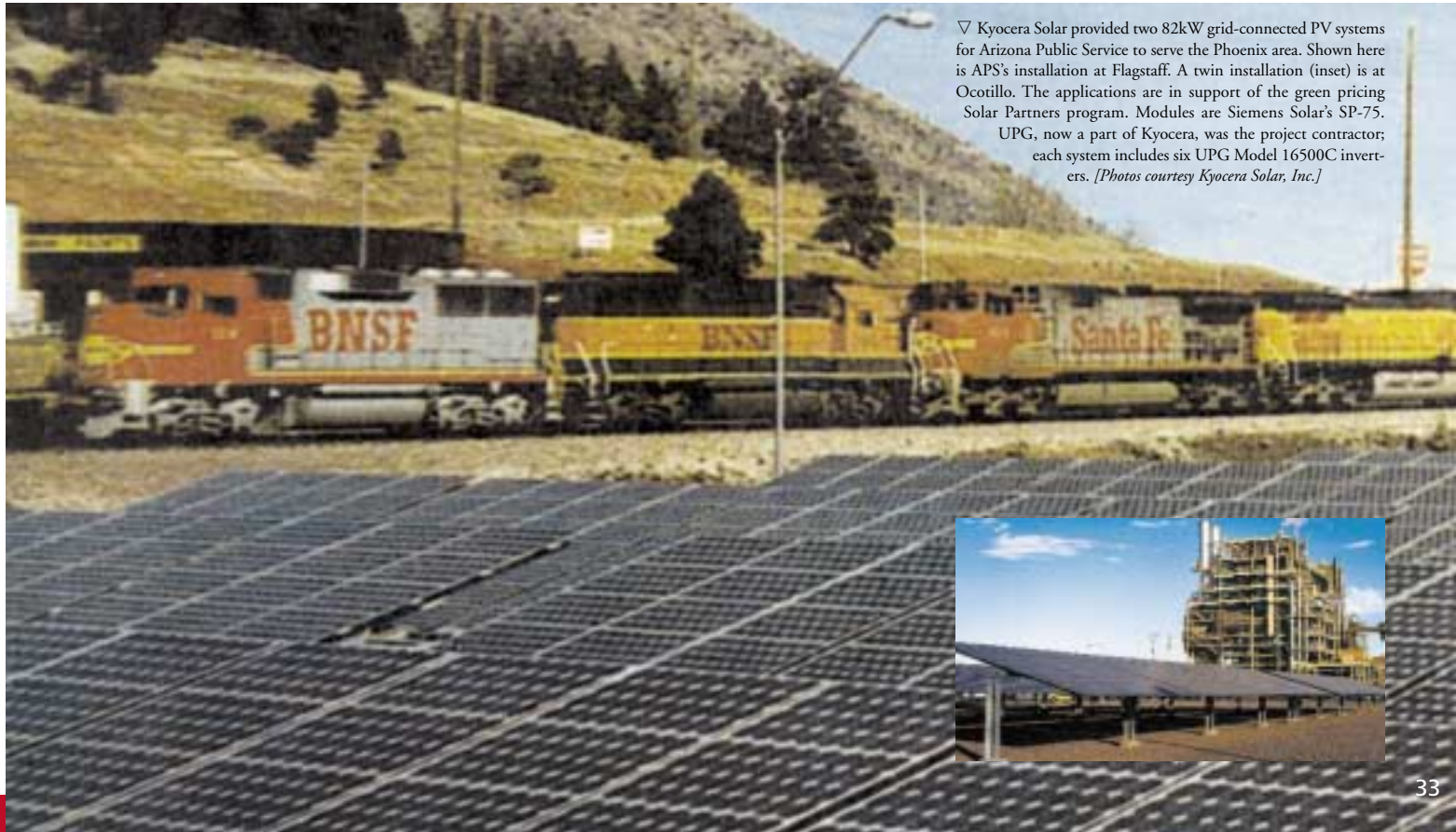
▽ A 100W Solar Electric Power assembly operates a digital computer monitoring system that measures a city's incoming water supply. PV performs reliably over the long term in monitoring the flow of water, gas, oil, and so on. *[Photo courtesy Solar Electric Power Company – SEPCO]*

△Solarex provided this 7kW remote system for Southern California Edison at Big Creek, Mammoth Mountain. Shown is one of the arrays featuring 60 MSX-60 modules. ***[Photo courtesy Solarex]***

◁ This 129kW PV single axis tracking system for Sacramento Municipal Utility District is located at the city's municipal airport. In addition to providing utility power, it serves as a parking lot shade structure. *[Photo courtesy Kyocera Solar, Inc.]*

◁ One of two 100kW single axis grid-connected PV tracking systems installed by Kyocera Solar for the Salt River Project, Phoenix, Arizona. The modules are Siemens SP75s. *[Photo courtesy Kyocera Solar, Inc.]*

▷ Cathodic protection of pipelines is one of the most appropriate and common uses for photovoltaics by utility companies, as it provides an economical and effective solution to corrosion problems. The solution is an electrical current from a PV source to counteract the natural corrosive currents generated around buried metallic devices. *[Photo courtesy Kyocera Solar, Inc.]*



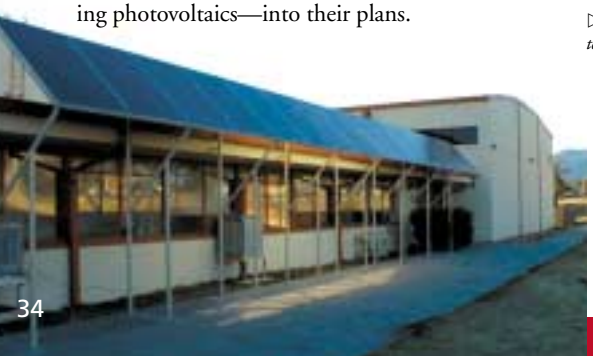
▽ Kyocera Solar provided two 82kW grid-connected PV systems for Arizona Public Service to serve the Phoenix area. Shown here is APS's installation at Flagstaff. A twin installation (inset) is at Ocotillo. The applications are in support of the green pricing Solar Partners program. Modules are Siemens Solar's SP-75. UPG, now a part of Kyocera, was the project contractor; each system includes six UPG Model 16500C inverters. *[Photos courtesy Kyocera Solar, Inc.]*

The U.S. military complex (Army, Navy, Air Force, Marines, Coast Guard, and national and state militia units) have many very remote sites in their arsenals. This fact makes PV particularly valuable for some military applications.

Several military telecommunications applications may be seen in other sections of this book as well. The applications of interest to military procurers of PV are quite diverse, particularly when size is taken into consideration. Some of the military's sites consist of a simple, small PV array tied to one battery. Others, such as the huge grid-tied array at the Yuma Proving Ground provide power for an entire building complex and more.

The functions of the military's many PV installations are diverse too, ranging from one of the most fundamental applications—water pumping—to one of the most futuristic—satellites.

Whatever the size, whatever the application, it is a fact that the Department of Defense is the largest energy consumer in the federal government, so it follows that the military complex will continue to find ways to integrate renewable energy—including photovoltaics—into their plans.



△ This 18kWp grid-connected system was installed by Ascension Technology as part of an EPA/DOE/DoD program at Ft. Dix, New Jersey for the U.S. Army. *[Photo courtesy U.S. Army]*

▷ A PV-powered crosswalk is in use outside the Pentagon. *[Photo courtesy U. S. Army]*

◁ This grid-tied installation is on Barnes Field House at Fort Huachuca, Arizona. Installed by AAA Solar, Albuquerque, New Mexico, it consists of 16 ASE Americas polycrystalline 285W modules. The dc output was inverted to 120 volts ac by a 6000W Omnion true sine wave inverter and wired back into the electrical grid in the building service entrance equipment. The system was designed to offset the peak load of the Fort and also provide the west-facing offices with much needed afternoon shade. *[Photo courtesy AAA Solar]*

▷ PV powers lights for a jogging trail on Charleston Air Force Base, South Carolina. According to the base energy manager, he preferred solar to conventional electrical lights in order to avoid transformers and buried cables. *[Photo courtesy Solar Outdoor Lighting]*

△ First Solar (formerly Solar Cells, Inc.), Toledo, Ohio, provided this 25kW dc system used at the Naval Air Warfare Center, Weapons Division, China Lake, California, at a fuel cell experimentation site. NASA uses the off-grid installation for experimental purposes, indicating its interest in PV working in tandem with fuel cells. *[Photo courtesy First Solar, LLC]*

◁ A 1200 watt portable, unbreakable solar array such as this one provided power for the U. S. government in operation Desert Shield. The panels are by Solarex. *[Photo courtesy Atlantic Solar Products]*

◁ Portable solar charging units provide power even with bullet holes and partial shade. Several companies manufacture these lightweight, tough units for use not only by military units, but also for anytime remote communications or emergency power are necessary. Shown here is Uni-Solar's Uni-Pac, which uses their triple junction technology. *[Photo courtesy United Solar Systems Corp.]*

△ The military often uses photovoltaics to power remote facilities, such as this area lighting at a remote equipment storage facility at Fort Huachuca, Arizona. *[Photo courtesy U.S. Army]*

▽ Shown here is a 441kW grid-tied PV array at Yuma Proving Ground, Arizona. The panel assemblies are attached to a torque tube that rotates to track the path of the sun during the day. PV is ideal for YPG because it can generate the most electricity during peak demand and also provide back-up power for the base's water supply should there be a power outage. *[Photo courtesy U.S. Army]*

◁ A major defense contractor needed an instrumentation power source that would be reliable even if military base power was lost. *[Photo courtesy Evergreen Solar]*

◁ This U.S. Army installation at Ft. Carson, Colorado, takes advantage of photovoltaics for a water pumping project. *[Photo courtesy U.S. Army]*

Consider for a moment the impact that a power source such as photovoltaics can make on the earth's environment. It is clean and considered non-polluting. It is a renewable energy source that consumes a reasonably small amount of the earth's resources to produce electricity. It is silent. Few resources are needed to keep it running, day, after day, after day, anywhere the sun shines.

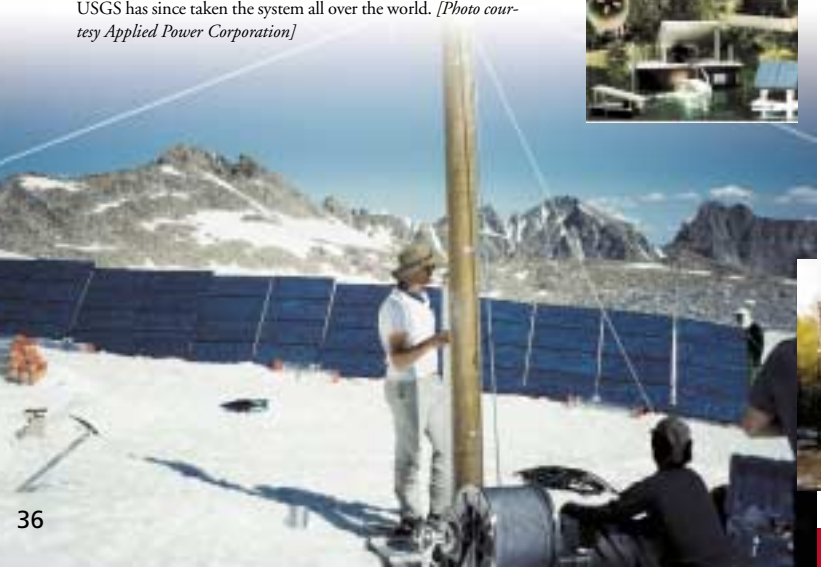
So, PV as a power source is itself a huge, positive influence on our environment. With that as an incontrovertible fact, what we feature here are ways in which PV is being used to promote environmentally sound projects—good works that use PV in a number of diverse ways.

△ Reynolds Aluminum uses a trailer-mounted PV system to monitor the air quality around a bauxite tailings "pond" covering several hundred acres near Corpus Christi, Texas. The trailer was customized by Direct Power and Water, Albuquerque, New Mexico. Samples are taken for a 24-hour period every seven days. The power system is configured for 12VDC and consists of 16 Siemens SP-75 75W modules using a battery bank of 10 Deka 8L16, 375 AH batteries. A Statpower 1,500W inverter is used to power the sampler and other related equipment. *[Photo courtesy Direct Power and Water]*

△ Live Oak Solar's portable T-REX PV system is on its way to a residential construction site in southern California. The PV unit was quiet enough to provide the necessary noise abatement for night-time building. *[Photo courtesy Live Oak Solar]*

▽ Professor Emeritus Bill Peterson, University of Illinois Agricultural Engineering Department is funded partly by the Illinois Bureau of Energy and Recycling (and partly by the National Renewable Energy Laboratory) to demonstrate PV projects from his mobile flatbed trailer. He uses a number of documents from Sandia's Photovoltaic Systems Assistance Center to educate his audience, whom Peterson reports are pleased when they see the many possibilities for using PV to save the environment. *[Photo courtesy Professor Bill Peterson]*

▽ The U.S. Geological Survey uses this portable Solarex solar system to take ice core samples from glaciers to study air quality. This photo was taken at Fremont Glacier, Wyoming, but the USGS has since taken the system all over the world. *[Photo courtesy Applied Power Corporation]*



▽ Simpler Solar, Tallahassee, Florida, provided this collage of components of their solar pond aeration system. As rain water washes over streets, roofs, farm lands, and so on, it builds up an excess of nutrients that result in excessive weed and algae growth. This accumulation consumes inordinate amounts of oxygen in ponds. Aeration systems bring new life to these bodies of water, and they are especially suited to be powered by photovoltaics. *[Photo courtesy Simpler Solar]*

◁ At the Miner Institute in Chazy, New York, an 1800W PV/propane generator hybrid system provides utility grade electricity to power a variety of instruments. This environmental research facility monitors the effect of environmental changes on atmospheric carbon releases from the temperate forest. The PV array consists of 25 Siemens modules. SunWize Technologies, a Besicorp company, provided the system, which was developed in partnership with the New York State Energy Research and Development Authority. *[Photo courtesy SunWize]*

△ Protecting the fragile environment was a strong motivation for having PV installed at his north Florida home, according to Al Ford, great-grandson of the famous automaker. Living through the aftermath of Hurricane Andrew—months of no running water or flush toilets or air conditioning—was an equally convincing reason to turn to PV. The large system includes Siemens panels, Zomeworks trackers, Trace Engineering inverters, and Trojan batteries. *[Photo courtesy Energy Conservation Services of North Florida]*

▽ A rainbow complements PV arrays designed and installed by The Solar Connection for The Nature Conservancy on Santa Cruz Island off the California coast. Photovoltaics replaced a noisy, smelly generator to provide power for up to 100 people who stay on the island at any given time, with enough power for their scientific work as well—about 35kW. The system features Siemens modules, C&D batteries, and a Trace Technologies inverter. In this fragile nature preserve, PV is the most appropriate technology. *[Photo courtesy The Solar Connection]*

▽ In a wetlands rehydration system installed by Solar Electric Power Company, Florida, a 900W assembly operates two remote water pumps in a 24V PV direct configuration. The pumps provide an average of over 10,000 gallons daily. The water is directed onto a designated wetlands replacement area. *[Photo courtesy SEPCO]*

▽ Lamar Buffalo Ranch, Wyoming, within Yellowstone National Park, uses a 5kW remote power PV system for electricity for NPS rangers, as well as instructors and students who convene there during the summer for ecology classes. *[Photo courtesy Altair Energy]*

▽ A Dankoff Solar centrifugal pump removes excess treated wastewater from a wetlands treatment system by means of spray irrigation. Second Nature Systems, Kennard, Texas, installed the solar irrigation system at the Transco Station gas pipeline sewer and industrial washdown near Sour Lake, Texas. Modules are from BP Solar. The array provides 675 watts of peak power. *[Photo courtesy Second Nature Systems]*

A hurricane strikes, bringing with it a tremendously destructive force that leaves a community without power. Or a flood, tornado, or earthquake occurs with little warning, disrupting normal communications. Emergency management teams, the national guard, and a myriad of other organizations respond with massive relief and rebuilding efforts. Food, water, and medical supplies are provided to survivors.

This scenario, unfortunately repeated numerous times a year, is one in which photovoltaics can play a vital role. Portable power systems, such as those equipped with PV, are capable of providing the electrical needs for vaccine refrigeration, microscopes and other medical equipment, lighting, radios, fans, communications, and traffic control devices, to name just a few. The energy provided is clean, quiet, and reliable. Stand-alone systems require no refueling, and they can operate for long periods of time. In fact, PV-powered systems are particularly appropriate for low-power needs and long-term use.

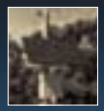
Portable photovoltaic power has been on the scene during Hurricanes Andrew, Hugo, Erin and Luis; at the destruction after the Northridge, California, earthquake; and at other catastrophic events. Continued training of emergency management teams will create an even larger niche for photovoltaics in these unfortunate situations.

◁ PowerPod's mobile power center suits a wide range of applications, especially radio communications, medical refrigeration, and outdoor lighting in the event of a natural disaster. A typical small pod would include a 100W PV panel, two 100 amp hour batteries, and an inverter for ac loads. These units have been deployed in Antarctica at McMurdo Station where they provide power for communications and monitoring equipment to measure global warming. *[Photo courtesy PowerPod/Sundance Solar]*

▽ After Hurricane Andrew in Dade County, Florida, this PV-powered street light was the only illumination surviving the destruction within five miles. Solar power kept the lights on in several communities for the two- or three-week period until utility power could be restored. The 64W system shown here was installed by Solar Outdoor Lighting, Stuart, Florida. *[Photo courtesy Solar Outdoor Lighting]*

◁ SunWize mobile PV power units provide electricity for the homes of elderly residents of Knotts Island, North Carolina after Hurricane Fran. *[Photo courtesy North Carolina Solar Center]*

◁ A Kyocera Solar module in Northern Arizona used for weather data instrument collecting and transmitting. *[Photo courtesy Kyocera Solar, Inc.]*



◁ Solar-powered early warning sirens, such as this one installed by Solar Depot, are found at nuclear power plants across the U.S. *[Photo courtesy Solar Depot]*

◁ Direct Global Power, Inc. has developed a portable PV-powered system for furnishing critical energy services during extended power outages following natural disasters such as hurricanes, floods, and earthquakes. This skid-mounted unit incorporates 16 AstroPower 1200W modules and a Trace sine wave-type 8000W continuous rating inverter. *[Photo courtesy Direct Global Power]*

◁ Global positioning systems may be powered with photovoltaics, such as the Solarex MSX-20 Lite™ system used for this Mount Everest seismic movement expedition. *[Photo courtesy Solarex, © Macgillivray-Freeman]*

▽ The Pacific Northwest Seismograph Network maintains many photovoltaic-powered monitoring stations like the one shown here on Mt. Rainier, Washington, where seismic data are collected and transmitted to assist in forewarning about earthquakes and volcanoes. *[Photo courtesy Pacific Northwest Seismograph Network]*

Some of the greatest human interest stories relating to photovoltaics come from the one-on-one impact that PV can make in the health of people in the developing world: PV is used to refrigerate vaccine, to create safe drinking water, to keep life-saving blood supplies under refrigeration, to pump fresh water where there was only a polluted stream before.

And PV can have that same impact on the safety of people, too. Fire fighters use PV in numerous ways. PV is used to ensure that test ban treaties are honored. In fact, the uses for PV are so diverse that they are limited only by the imagination of the user.

Whatever the future applications of PV may be, it is a certainty that it will continue to make us healthier and safer.

◁ PV helps power the Oxnard, California Fire Station Number Seven, which is a line-tied system designed and installed by Solar Electrical Systems, Thousand Oaks, California. The customer is SCE, the modules are 12kW AstroPower, with an Omnion inverter. *[Photo courtesy Solar Electrical Systems]*

◁ International health organizations use solar panels to power refrigeration units in developing countries and in emergency situations anywhere in the world. This application saves lives by refrigerating precious blood and vaccines. *[Photo courtesy GeoSolar Energy Systems, Inc.]*

◁ Here a 768 watt Solarex array powers a water chlorinating station. *[Photo courtesy Atlantic Solar Products]*

◁ This solar-powered water purification and disinfection unit uses the power of the sun to provide clean, microbiologically safe drinking water. Units such as this are critical in areas struck by natural disaster or areas where the only source of drinking water is contaminated. *[Photo courtesy Southwest Photovoltaics]*

◁ This installation at Long Tom Look Out on the Bitterroot National Forest, Montana, powers a two-way radio system for USDA Forest Service firefighters. Installed by Sunelco, it uses 24 Solarex 60W modules. *[Photo courtesy Kyocera Solar]*

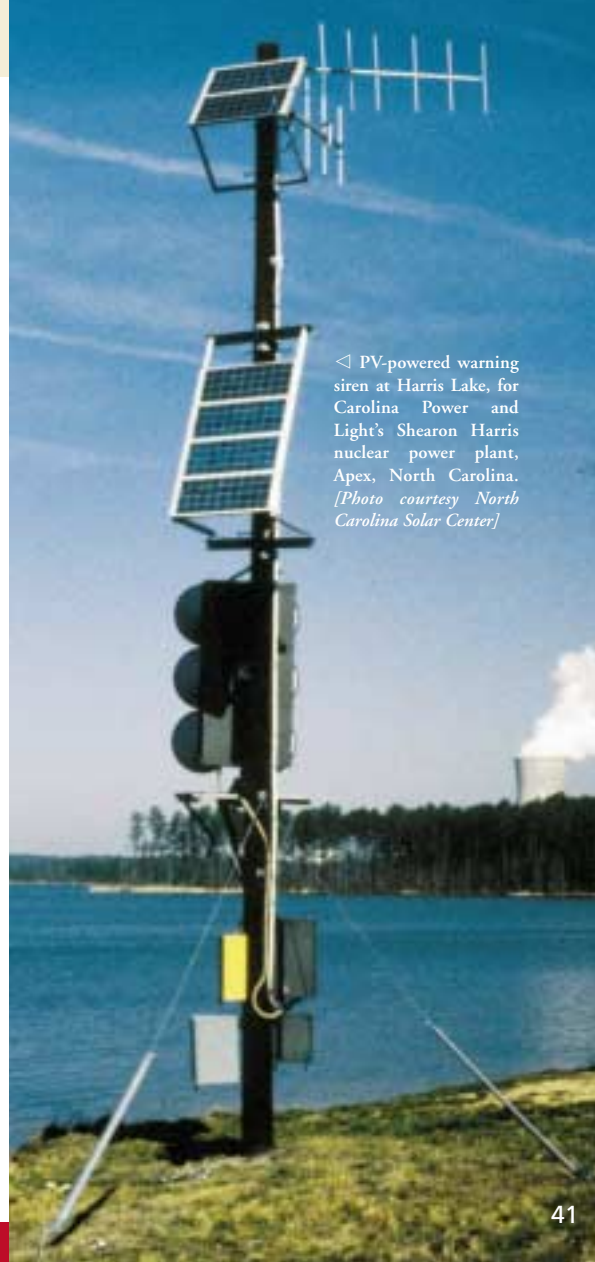
◁ A project undertaken by Direct Global Power, Schenectady, and the New York State Police, proved the efficacy of a PV power option atop Cathead Mountain (shown here) and Black Mountain, both within the Adirondack Preserve. Thirty-six Siemens modules designed to produce about 2kW under peak conditions augment existing systems at both locales. Reliability and spatial coverage of the State Police's radio communications systems have been increased. *[Photo courtesy Direct Global Power, Inc.]*

◁ Some perfectly viable applications for photovoltaics may result in curiously interesting photographs, but small PV-powered refrigeration units for items such as vaccines is a very important application for PV in developing countries—or in the event of major weather occurrences or natural disasters where conventional power is lost here in the United States. *[Photo courtesy Siemens Solar Industries]*

◁ A PV-fed water treatment plant is part of the Army's Yuma Proving Ground complex. Shown here are the plant, the processing tanks, and the "long line" 12.47KV switch. *[Photo courtesy U.S. Army]*

▽ A PV hybrid system (2.2kW PV array and two diesel generators) powers this International Nuclear Test Ban Treaty seismic monitoring station in Antarctica. The system, located at Bull Pass, was designed, manufactured, and installed by Northern Power Systems, Waitsfield, Vermont. *[Photo courtesy Northern Power]*

▽ In northern California, where wildfires sometimes destroy thousands of acres of land, these deployable PowerPods are used by fire fighting crews in base camps and staging areas. They provide power for integrated flood lighting, ac inverter power for computers, radio battery charging, and communications equipment. *[Photo courtesy PowerPod Corporation]*



◁ **PV-powered warning siren at Harris Lake, for Carolina Power and Light's Shearon Harris nuclear power plant, Apex, North Carolina.** *[Photo courtesy North Carolina Solar Center]*

Creating beauty. Creating convenience. Creating pleasure. Photovoltaics can change our lives and change the look of the world around us. PV can have a powerful impact on our everyday lives, whether we're working or playing.

Solar-powered calculators and watches have more than two decades of successful history; in fact, that early application of PV is all but taken for granted today.

Photovoltaics has been incorporated into the total energy package at dozens of our national parks and monuments—places where we enjoy America's vast natural beauty. PV—a quiet, clean source of energy—is, in fact, used because it keeps America beautiful.

Now solar is being marketed in conjunction with other consumer products as well. Some of those are shown here, but only the future will tell what other uses there may be for PV-powered objects in our daily lives. Some predict that soon automobiles will all be equipped with PV on car roofs or hoods so that satellite links can supply 'video on demand for the back seat.'

The next two double-page spreads are dedicated to PV for recreational purposes or for enhancing everyday life.

Take a look around you. The possibilities are endless.

△ The Sullivan cabin at Pictured Rocks National Lakeshore has a PV shingle roof array of about 2kW on a ranger cabin. The Uni-Solar PV shingles serve as both a roof shingle and a solar collector, and help maintain the rustic appearance of the cabin. The system was designed and installed by Currin Corporation for the National Park Service. The roof is covered with snow from December to April, so a pole-mounted array is used to maintain a charge on the 48V battery bank. The cabin is unoccupied and inaccessible during the winter months. *[Photos courtesy Currin Corporation]*

▷ A 24V solar-powered water pumping system is located at the picnic area/trailhead at Pictured Rocks National Lakeshore, Grand Marais, Michigan. Called the Log Slide Pumphouse, the installation was designed by Currin Corporation and is contained in the kiosk structure that also serves as an information station and storage building. *[Photo courtesy National Park Service]*

◁ Small arrays such as this one by Kyocera Solar provide power wherever you need it—such as on a pleasure craft or fishing boat. *[Photo courtesy Kyocera Solar, Inc.]*

▷ A rather large market exists for small PV arrays to power lights and household appliances in recreational vehicles. Shown here are two Uni-Power US-21 modules used for battery charging in an RV. *[Photo courtesy United Solar Systems Corp.]*

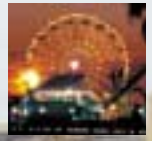
▽ PV modules are roof mounted (to deter vandalism) on the General Nathan Twining Observatory located near Belen, New Mexico. The installation was designed and integrated by Energia Total, Corrales, New Mexico, through an Enchantment Energy Trust grant from Public Service Company of New Mexico. The array is capable of producing 90 watts of power. The Albuquerque Astronomical Society owns and operates the facility. *[Photo courtesy Michael Pendley]*

▷ PV is becoming ever more visible. This array by SMUD provides power at the Sacramento, California Municipal Zoo. *[Photo courtesy Sacramento Municipal Utility District]* and 5kW of thin film, amorphous silicon modules by Energy Photovoltaics (EPV) provides both shade and power over bleachers at the Roseville, California city pool. This was a project installed by UPG (now Kyocera) for SMUD. *[Photo courtesy Kyocera Solar, Inc.]*

△ This BP Solar Apollo® glass pavilion was created for the Cooper-Hewitt National Design Museum, part of the Smithsonian Institution, New York City. The pavilion is now a traveling exhibition showcased in major cities around the U.S. as part of *"Under the Sun: An Outdoor Exhibition of Light,"* which focuses on innovative solar design and architecture. *[Photo courtesy BP Solar]*

▷ Solar-powered golf carts are used at the Mauna Lani Hotel, Kohala Coast, Hawaii. When a cart is at rest, PowerLight's SunCaddy charges the battery; and an integrated charge controller ensures that the batteries will not be overcharged. SunCaddy works on any golf cart through a simple roof-top installation. It has no moving parts and is designed for practically maintenance-free operation. *[Photo courtesy PowerLight Corporation]*

◁ The design of this solar-powered fountain integrates PV cells on a curved surface to catch the changing angles of the sun. They are specially sized, configured, and wired polycrystalline cells on custom-designed modules from Kyocera Solar. The fountain is depicted among the Cooper-Hewitt National Design Museum's images in their "Under the Sun" exhibit. *[Photo courtesy Alt. Technica]*

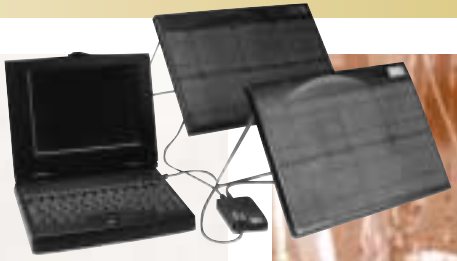


◁ Solar takes a happy turn at a seaside park at the Santa Monica Pier (California) where a 50kW Siemens Solar system is one of a number of high visibility demonstrations that build public awareness of the environmental value of renewable technologies. This is the world's first solar-powered ferris wheel. *[Photo courtesy Siemens Solar Industries]*

▷ Everyday life for children of the Laguna Pueblo in New Mexico will be enhanced when the proposed Laguna Youth Facility at the old Majors Ranch becomes a reality. The existing PV will be augmented with 2kW of PV for electricity and a 1.2kW PV system for water pumping to power the main house, a dormitory for kids, and other outbuildings. A wind turbine will provide 10kW of electricity. The ranch is 10 miles off-grid. *[Photo courtesy Diversified Systems Manufacturing]*

Serenity Studio, Prescott, Arizona, is the first known solar-powered sound recording studio in the U.S. PV power ensures no electrical surges or power outages. The studio uses about 1000 watts of power in full operation and is powered by 14 Siemens 75 W panels with a Trace inverter—tied to PV on an adjoining residence. *[Photo courtesy Carol Hills]* ▽

▷ The Indian Pueblo Cultural Center, Albuquerque, New Mexico, integrates a PV awning beautifully with its building. The Zia design was cut into the center row of panels, creating a stunning effect when sunlight paints the sacred Indian symbol onto the sidewalk below. Native American-owned Diversified Systems Manufacturing designed and oversaw the project. Energia Total, Corrales, installed the system, which incorporated AstroPower modules. The solar carport is the largest commercial PV array in the state. *[Photo courtesy Sandia National Laboratories]*



▷ PV provides portable power for computers. This SunWize unit means you can work away from the electrical grid as long as the sun is shining to power the portable energy system. *[Photo courtesy SunWize]*

▽ This PV-assisted, grid-connected clock tower is the centerpiece of SunMicrosystems $200 million campus in Burlington, Massachusetts. Modules were provided by ASE Americas. The outstanding design was created by architect Sun-Hok. *[Photo courtesy ASE Americas]*

◁ PV provides power where you need it on recreational vehicles of all kinds—even those on water. *[Photo courtesy Kyocera Solar, Inc.]*

△ Solar-powered refrigerators provide the security of foodstuffs in emergency or back-up power situations. Shown here is the SolarFridge by Simpler Solar, Tallahassee, Florida. *[Photo courtesy Simpler Solar]*

▷ PV for wireless communications is a welcome addition. If you're stranded because of an auto malfunction, car phones—made possible by solar power—provide security, safety, and relief. *[Photo courtesy Kyocera Solar, Inc.]*

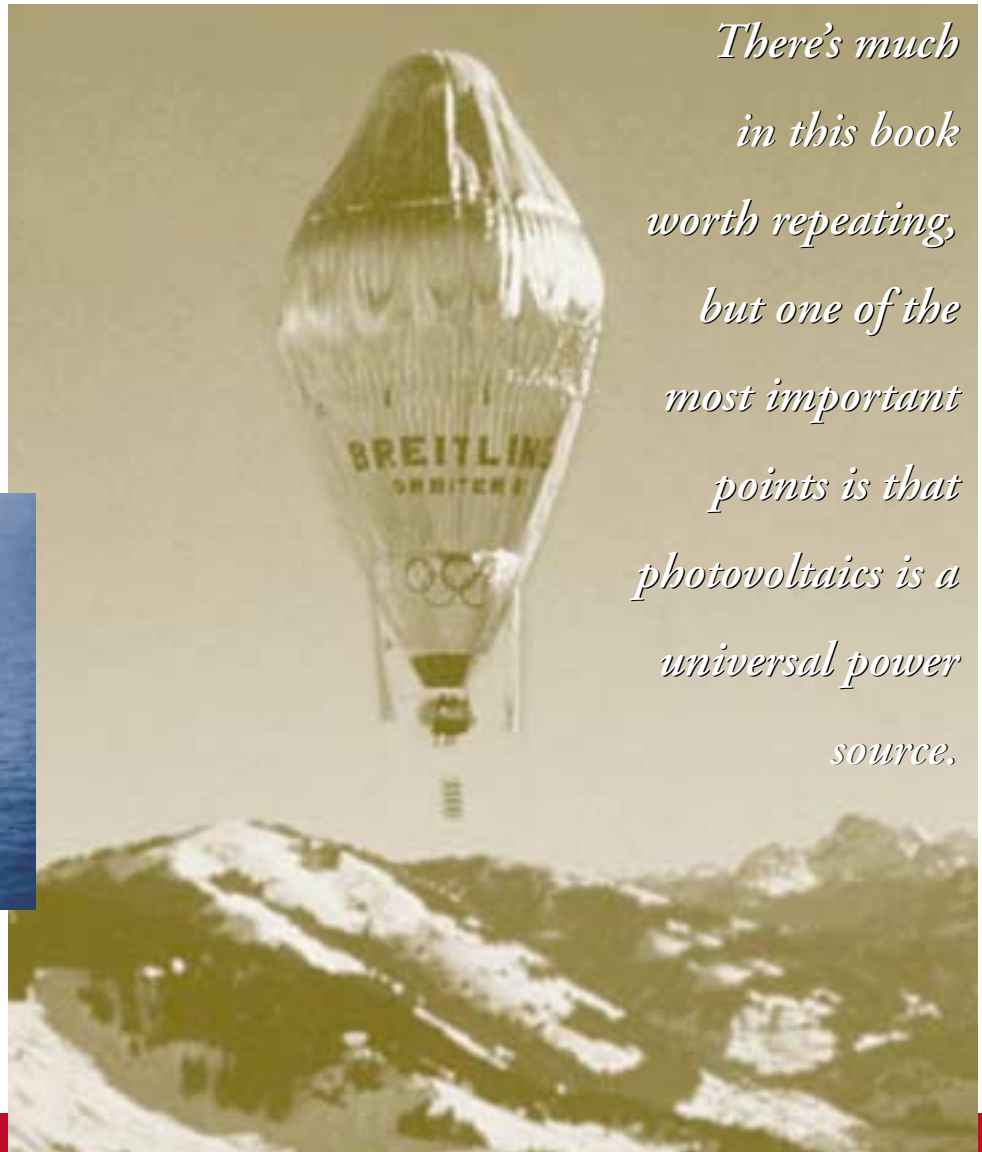
▷ Lawnmowers in the U.S. burn nearly 800 million gallons of gas each year. One response is this Solar Mower™. *[Photo courtesy The Green Culture]*

▷ This solar-powered lantern is great for camping or emergency use. Have light anywhere you need it, free of lines, propane tanks, and messy lamp gas or oil. A full charge provides 4-6 hours of light. *[Photo courtesy Solar Utility]*

We've shown you PV at work in diverse and creative ways you might never have imagined. And while we've developed some categories to group ideas together, these categories are in no way meant to limit how you think about PV. On the contrary, expanding the options for which we consider photovoltaics is the whole purpose for this book.

▷ The Breitling Orbiter III became the first hot air balloon to circle the globe non-stop. Morningstar's ProStar controllers were used to manage the electricity generated by the 20 Solarex PV panels hanging under the gondola. Energy for all on-board equipment—telecommunications and navigation instruments, lighting, and water heater—was stored in five batteries. *[Photo courtesy Morningstar]*

△ Pathfinder is a remotely controlled, solar-powered flying wing, designed and built as a proof of concept vehicle for a much larger aircraft capable of flying at extremely high altitudes for weeks at a time. It was built for NASA by AeroVironment, a California company. Current from solar arrays (silicon solar cells developed by SunPower Corporation) provides power during daylight, while stored energy allows flight after dark. *[Photo courtesy NASA]*



There's much in this book worth repeating, but one of the most important points is that photovoltaics is a universal power source,

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Solar Utility, Inc.
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www.solarutility.com

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www.southwestpv.com

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