Technical Assistance

Detailed Case Study

Installing renewable energy projects at Federal facilities provides Federal agencies an opportunity to fulfill their mandate for responsible stewardship of our national resources with cost-effective environmentally benign technologies.

Electrifying Pinnacles

A hybrid photovoltaic system provides Pinnacles National Monument with an elegant solution to the problem of providing electrical services in an environmentally sensitive area.

Superintendent Gary Candelaria is very enthusiastic about the photovoltaic (PV) installation at Pinnacles National Monument in California. "The PV system does everything we designed it to do, and it costs a fraction of what we used to pay each month to operate and maintain the diesel generators it replaces. Our diesel fuel costs alone were $20,000 a year."

The Pinnacles installation, which was finished in April 1996, is a state-of-the-art hybrid PV system installed within the National Park Service (NPS). It includes a 9.6-kilowatt (kW) PV array, a 4,200 amp-hour bank of flooded lead-acid batteries, and a 20-kW propane-powered backup generator. The hybrid system replaced two 100-kW Caterpillar diesel generators, derated to 57-kW for single-phase operation, that ran 24 hours a day, creating a constant din and polluting the air in this pristine area.

"We could hear the generator noise from the residences, offices, work spaces—even the trails and the surrounding peaks," explains Candelaria. "It was hard to enjoy the solitude and silence of the wilderness with the constant sound of machinery operating and the smell of exhaust. We had no idea there were so many birds in this area until the PV system came on line."

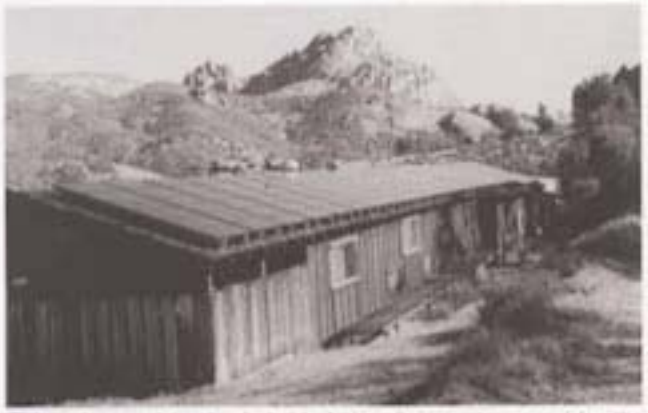
In addition to the noise and pollution, park service staff were concerned that the diesel generators were an environmental disaster waiting to happen. The need to transport diesel fuel to the site and store it in a large tank presented the constant danger of fuel spills or leaks in this environmentally sensitive region. And because the generators were oversized to meet an infrequent peak load, park personnel had to leave lights on to maintain a stabilizing load for the idling engines, wasting fuel and creating light pollution.

The local utility, Pacific Gas & Electric Company (PG&E), supplies power to the more developed east side of the park, but the cost to extend the grid to the undeveloped Chapparral area on the west side was prohibitive. For the utility, it was a losing proposition, because the site would be at the end of the power line—they could not justify maintaining a line for only one customer. Park personnel also worried about the environmental impact of running power lines through a wilderness area.

Finding a sustainable solution

Although the diesel generators had provided reliable power for decades, the environmental and aesthetic costs were becoming unacceptable, especially in light of the park service commitment to protect resources as well as provide services. In 1991, the National Park Service (NPS) identified sustainable design as the cornerstone of an effort to accommodate park visitors without compromising the ability of future generations to meet their own needs. In 1994, the U.S. Department of Energy (DOE) and Sandia National Laboratories (Sandia) collaborated with NPS to survey existing PV systems and assess the potential for future installations at park facilities.

The survey revealed as many as 600 PV projects already operating in the national park



National Park Service/FOE/7/21

This quiet, unobtrusive hybrid photovoltaic system provides the Chapparral area on the west side of Pinnacles National Monument with clean, reliable electricity. In this pristine area, the photovoltaic installation eliminates park service staff concerns about fuel spills or leaks, because the PV system requires no fuel and produces no emissions.

U.S. Department of Energy

system, and park personnel reported that 97% of them were working well. The survey also asked for suggestions for future projects, and park staff responded with 643 proposals totaling $28 million! More than 30 of these projects, including Pinnacles, are now complete or in process.

National Park Service/PIX06723

The designers divided the electrical service into two separate single-phase lines to keep the maximum single-phase load below 16 kW, which allowed the use of less expensive off-the-shelf inverters. All the equipment for this project was purchased off the General Services Administration supply schedule.

In January 1995, Sandia and park service engineers from the Denver Service Center assessed the Chaparral area on the west side of Pinnacles to determine if it was a candidate for a PV hybrid power system. The site requirements included power for a maintenance shop, three employee houses, a ranger station, visitor center, comfort station, campground, well pump, two effluent wastewater pumps, and a parking area. Sandia's Photovoltaic Systems Assistance Center provided Pinnacles personnel with an analysis of the site's electrical loads, a solar resource assessment, a summary of the power options available, and a recommendation that they replace the diesel generators with a hybrid PV system.

The PV system would be a quieter, less polluting, more fuel-efficient means to meet the power needs of the site. As Gary Candelaria put it, "The PV hybrid hits all the right notes in the NPS mandate to protect and preserve our parks and still provide services to visitors."

New hybrid systems in the national parks often use propane generators instead of diesel units, because propane gensets are cleaner, quieter, and more suited to these installations' short duty cycles. Propane is environmentally safer than diesel fuel because accidental propane spills will evaporate rather than contaminate the ground, and propane does not produce as much air pollution. In addition, hybrid system designers prefer propane gensets because the generators in these installations run infrequently—the PV provides most of the power—and the propane generators need not be left idling and do not require a stabilizing load.

Energy efficiency first

Through Sandia, DOE determined that the Pinnacles project met their funding guidelines for matching funds. Sandia and park service personnel then developed a plan to install the PV system. A critical component of the proposal was an integrated program of energy efficiency, load management, and load segmentation that cut the energy requirements at the site in half (from an average of 81 kWh/day in 1995 to 41 kWh/day in 1997). To accomplish this, the designers specified the installation of energy-efficient lamps to reduce the lighting load, low-flow devices to reduce water-pumping loads, and electronic controls to stagger the starts of pump motors to minimize in-rush surges.

The plan also called for replacing electric stoves, clothes dryers, space heaters, and water heaters with propane-fueled units, and dividing the electrical service into two separate single-phase lines to keep the maximum single-phase load below 16 kW. This tactic allowed the use of less expensive off-the-shelf inverters—in fact, all the equipment for this project was purchased off the General Services Administration supply schedule.

Economics

NPS now bases development decisions on life-cycle cost analyses, which include the cost of operating and maintaining installations throughout their anticipated service life. These analyses also assign dollar values to the costs of energy use that are usually hidden—air pollution, fuel spills, and other environmental damage, for example. This is good news for renewable energy technologies, because although they are typically expensive to purchase, they require minimal maintenance, no fuel, and produce no emissions.

Although the park service chose the Pinnacles PV hybrid system because it offered significant environmental benefits, a life-cycle cost analysis shows that the PV hybrid system also costs about $83,000 less than two replacement propane gensets over a 20-year life cycle. In addition to dollar savings, the PV hybrid saves more than 8,000 gallons (30,250 liters) of propane fuel each year (more than 162,000 gallons [613,170 liters] during the 20-year service life of the system). If the costs NPS has assigned to emissions of carbon dioxide, sulfur dioxide, and nitrous oxide are included in the analysis, the PV hybrid system saves more than another $24,000 over 20 years and avoids over 1,000 tons (909 metric tons) of CO_2 and 1.5 tons (1.4 metric tons) of NO_x. If the gensets were diesel instead of propane, the savings would be even more impressive. The original Pinnacles' diesel generator produced 143 tons (130 metric tons) of CO_2, 6,900 pounds (3,130 kilograms) of NO_x, and 343 pounds (155 kilograms) of SO_2 every year.

Performance

The hybrid PV system continues to function well and has excellent availability and reliability. From May through September 1997, the PV array provided virtually all the energy used at the site. The loads are slightly higher in winter, because of the increased lighting load and the need to pump winter ground water that infiltrates the sewer system. In addition, insolation levels are lower. During the course of a year, the propane generator runs only 793 hours and burns 1,265 gallons (4,800 liters) of fuel.

"If it were up to me," says Candelaria, "I would power the entire park with photovoltaics. The utility power on the east side of the Monument seems to go out an average of once a week—the PV hybrid system is far more reliable."

Assuring success

Careful planning and good communication can help assure the success of renewable energy installations. PV hybrid systems are different in several ways from the conventional generators that they replace, which can cause some resistance on the part of facility staff. They cost more to purchase, are more complex, their batteries require maintenance, and they use technologies that may be unfamiliar to maintenance personnel.

However, the PV system's many advantages make the resistance worth overcoming. The clean, quiet electricity it produces creates a more pleasing experience for the staff and visitors than the noise and pollution of the diesel generators. Because it requires less (and safer) fuel, the PV system also protects the local environment from air pollution and the risk of fuel spills and leaks. And the PV system is less expensive on a 20-year life-cycle cost basis.

Another strategy to smooth the process of installing a renewable energy system is to establish a spirit of collaboration and a commitment to success from the outset, and choose suppliers and contractors who share that enthusiasm. According to Candelaria, "One of the keys to the success of this project was the wonderful partnerships that developed among the individuals and organizations involved. Everyone was committed to making the project work."

The big picture

Installing renewable energy projects at Federal facilities provides Federal agencies an opportunity to fulfill their mandate for responsible stewardship of our national resources with cost-effective, environmentally benign technologies that do not contribute to global climate change. Federal agencies administer more than 31% of the land area in the United States, and a large percentage of this land is remote and environmentally sensitive. In many of these areas, the need for services that require electricity is increasing.

Federal programs that encourage sustainable solutions to these needs help create a market for renewable energy technologies. For example, Renew the Parks (a partnership among the DOE PV Division, Sandia, and the National Park Service) has identified several hundred national park locations in need of power that would best be served by photovoltaics. In addition, information at high-profile sites can help educate the public about the benefits of renewable energy technologies, which include reducing emissions of gases believed to cause global climate change.

To other facility managers who are considering a renewable energy installation, Gary Candelaria extends an invitation. "Come visit our system and see how quiet and unobtrusive it is. We save maintenance time and money, no longer have to worry about diesel fuel leaks and spills, and this system is sustainable! What more could you ask of a power system?"

20-YEAR LIFE-CYCLE COST ANALYSIS

	Base Case	PV Hybrid Case
INITIAL INVESTMENT		
Capital Requirements	$24,000	$135,000
FUTURE COSTS		
Recurring Costs*	$74,089	$10,399
Energy-Related Costs**	$164,888	$22,230
Capital Replacements	$31,790	$43,577
TOTAL PRESENT VALUE	**$294,767**	**$211,206**

* *Recurring costs include maintenance costs, such as oil changes for base case, watering batteries for hybrid system.*

** *Energy-related costs include fuel costs.*

Note that these numbers are based on a propane genset base case. The numbers would be significantly higher if the base case was a diesel generator.

NPS ASSIGNMENT OF EMISSION COSTS

	Before 9/97*	After 9/97*
CO_2	$8/ton	$14/ton
SO_2	$0.75/pound	$0.85/pound
NO_x	$3.40/pound	$3.75/pound

* *The NPS revised its emission costs in September 1997.*

PINNACLES ANNUAL EMISSIONS COST ESTIMATES

	Base Case	PV Hybrid
CO_2	59.3 tons	8.0 tons
SO_2	0.7 pounds	0.1 pounds
NO_x	179.7 pounds	24.2 pounds
ANNUAL COST	**$1,442**	**$203**

Note that these numbers are based on a propane genset base case. The numbers would be significantly higher if the base case was a diesel generator.

Project Description: Hybrid photovoltaic system

Owner: National Park Service, Paicines, California

Location: West District Pinnacles National Monument, Soledad, California

Design and Installation: Applied Power Corporation, Lacey, Washington/ Denver Service Center, National Park Service

NPS Design Engineers: Douglas DeNio (303) 988-3406/Douglas Richards (303) 969-2685

Sandia Design Engineers: Hal Post (505) 844-2154/Mike Thomas (505) 844-1548

PV Hybrid Power System Equipment:

- 9.6-kW photovoltaic array—160 Solarex MSX-60 modules
- 20-kW propane generator—Kohler 20RZ, configured for propane
- 4200-ampere-hour battery—12 model 6-75RC33 Resource Commander Batteries
- Battery charge controller—Ananda Power model APT-4444-48
- 24-kW inverter bank—6 4-kW Trace SW4048 120/240 inverters, configured as 4 in parallel serving one line and 2 in parallel serving the other line
- Dedicated data acquisition system to record PV, battery, load and generator energy; battery string currents; battery voltage, battery, PV and ambient temperatures; and irradiance.

For more information

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This case study is available on the FEMP Web site (**http://www.eren.doe.gov/femp**) and from the FEMP Help Desk (1-800-363-3732).

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FEDERAL ENERGY MANAGEMENT PROGRAM

For More Information

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