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Solar Energy Powers Remote Water Systems:

A US Environmental Protection Agency project proved solar energy's viability for small community water systems in Puerto Rico and other remote areas.

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About 96 percent of Puerto Rico's drinking water is produced and distributed by the Puerto Rico Aqueduct and Sewer Authority (PRASA). However, Puerto Rico has 242 non-PRASA public water systems in remote mountainous areas where PRASA can't provide coverage. Most of these systems serve between 100 and 500 people.

Filtration and disinfection technologies are limited in these small systems, with 76 percent reporting some form of chlorination and only 4 percent using filtration. Many non-PRASA disinfection systems aren't necessarily in operation, as 40 percent reported total coliform-positive results in fiscal year 2015. Rural non-PRASA communities face many challenges, including insufficient water supplies; intermittent electrical service; and a general lack of financial, technical, and managerial capacities to properly operate and maintain their water systems.

Small water systems have been proven to be successful if they're easy to install, operate, and maintain with community support and are designed to use local hardware store parts and supplies. With limited money to produce clean, safe drinking water and to pay for improvements, residents work collectively and volunteer to secure a consistent water supply to their homes.

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ENERGY IN PUERTO RICO

Puerto Rico imports petroleum, natural gas, and coal to generate electricity, resulting in electrical rates that are more than two times the U.S. average, according to the U.S. Energy Information Administration. Since 2012, the use of solar energy has increased by a factor of nine, but it still accounts for less than 1 percent of Puerto Rico's energy production. In 2015, only about 2 percent of the energy produced in Puerto Rico was from renewable energy (wind and solar). However, solar power is a viable renewable energy source for Puerto Rico because of the island's consistent sunshine and the high cost of importing other energy sources.

The electricity required to transfer, treat, and distribute drinking water is expensive for small communities in Puerto Rico, and many can't afford it. Some communities have abandoned their groundwater sources and reverted to unfiltered surface water systems, creating serious public health risks and noncompliance with Safe Drinking Water Act regulations. Solar-powered pumping systems could be used by most non-PRASA communities to extract and transfer source water for treatment and distribution.

In 2012, a conventional water treatment system was installed to treat water for 25 households in the upper watershed of Apeadero, Puerto Rico. The new water system was adopted by the community and will be used as a training location for operators from other small communities.

After installation, 50 more households in the lower watershed showed interest in tapping into the new water treatment system. The plant had the capacity to treat drinking water for 75 households, but it wasn't supplied with enough source water to meet the increased demand.

With steep terrain and limited municipal infrastructure, a plan was developed to use a solar-powered pump and water lines to supplement the water supply reaching the new water treatment system. The plan was developed by the U.S. Environmental Protection Agency (USEPA) and the InterAmerican University of Puerto Rico (IAUPR), which collaborated on a one-year project to design and install a solar-powered pumping system to transfer and combine water from two watershed sources in Apeadero.

USING SOLAR ENERGY FOR SAFER WATER

The project included many tasks with various activities performed by USEPA, IAUPR, consultants, operators, and community volunteers. The project team began the project by clearing a flat area a short distance above the lower water storage tank in Apeadero to install the solar panels. Global Positioning System (GPS) units were used to determine the elevation change (350 vertical ft) required for pump selection. Two types of GPS units were used because of uncertainties associated with the impact of the rainforest tree canopy on GPS elevation readings.

After a construction plan was finalized, the project team purchased construction materials for concrete block enclosures, an equalization tank, a water pump, a control cabinet, water

pipe, solar panels and frame, batteries, and an inverter system. These items were delivered via one-lane paved and dirt roads on steep hillsides. Rain often made the one-lane dirt roads impassable for two-wheel drive vehicles. After several rainstorms, a bulldozer was required to regrade the heavily rutted dirt road.

Because of the potential for hurricane and tropical storm force winds, the frame for the solar panels was anchored in the ground with concrete and constructed of galvanized steel pipe (3 in. in diameter), as shown in the photos on page TK. Twelve solar panels were mounted on the frame to accommodate electricity to operate the $\frac{3}{4}$ horsepower water pump. A concrete block enclosure was built by community volunteers to house and secure eight marine deep-cycle batteries and the inverter system, as shown in the photos on page TK.

During Hurricane Maria, the solar panels survived wind gusts of up to 110 mph. Fortunately, no large trees or flying debris destroyed the panels. A second concrete block enclosure was built by the community on top of the lower storage tank to house the solar-powered pump and control cabinet, as shown in the photos on page TK. The solar panels convert sunlight into DC electricity to charge the batteries. The inverter system converts the DC electricity into AC electricity to power the water pump and electrical outlets for lighting and power tools in this remote location.

A 250-gal equalization tank was rolled to the top of the steep hill, and a 1-in. water pipe was installed and secured aboveground to connect the equalization tank to the water pump at the bottom of the hill. A mechanical high-level float valve was installed in the equalization tank to prevent the tank from overflowing. The water pump control cabinet ensures the solar-powered pump's operation by shutting off the pump under low-flow conditions (to prevent motor burnout) and shutting off the pump when the storage tank is full, using the float valve to trigger shutoff. The pump is programmed to wait 10 minutes before restarting.

A programmable timer allows the operator to set operating hours and accommodate pumping at various times during the day. The solar-powered pump can lift surface water from the lower watershed 350 vertical ft to the equalization tank at a flowrate of up to 12 gal/min. The water in the equalization tank then flows to the water treatment system for treatment and distribution to Apeadero residents.

The solar-powered water system cost \$12,500, and the water pumping system cost \$2,500. The 245W system will produce 4,054 Kwh of energy per year. One long-term maintenance cost will be the need to replace the eight marine deep cycle batteries (\$2,000). The solar energy has extended the life of the system's electrical components by improving the quality of Apeadero's formerly intermittent and costly electrical power supply.

The system also delivers impressive environmental benefits. Using USEPA's Greenhouse Gas Equivalencies Calculator (www.epa.gov/cleanenergy/energy-resources/calculator), the solar panels will eliminate as much greenhouse gas emissions as not burning 3,040 pounds of coal/year, atmospheric carbon as is sequestered by 2.7 forested acres/year, or greenhouse gas emissions as not driving 6,828 vehicle miles/year.

COMMUNITY BUY-IN MATTERS

The project was designed to investigate the use of low-cost, energy-efficient water treatment technologies in Puerto Rico, the Caribbean, and other tropical regions. Community involvement and education were promoted during construction and implementation to ensure effective operation and maintenance of treatment processes and to reduce public health risks.

Communicating with residents in small communities and obtaining agreement on project plans is critical before, during, and after drinking water infrastructure improvement projects. Town meetings are key to obtain feedback from the residents and keep the community involved in all aspects of the project. Moreover, the support of community volunteers and local assistance is crucial to reduce costs in small communities. Based on the outcome of this project, solar power is a proven alternative to the high-priced and unpredictable delivery of electric power in Puerto Rico.