Article courtesy of Mechanical Engineering magazine, Mechanical Engineering Power, June 2001, pages 30-34; copyright Mechanical Engineering magazine (American Society of Mechanical Engineers).

Sun Shower

Solar energy is providing a way to reach clean water in remote areas far from electric grids.

By Henry Baumgartner, Assistant Editor

Over vast stretches of the surface of the earth, night still retains its ancient power. Although electrical grids now extend to cover most of the world's population, a good third of the world's population—two billion people, mostly poor and rural—have no access to electricity, according to Paul Klimas, the photovoltaics program manager at Sandia National Laboratories in Albuquerque, N.M.

Unfortunately, this is not just a matter of no TV or ice cream. Besides providing illumination and communications, one of the most important things electricity can do in many places is operate pumps to improve the water supply. Many remote, rural places located far from the nearest electric grid are chronically short of water; others are forced to rely on supplies that are polluted or brackish. Waterborne disease remains one of the world's greatest plagues—and one of its most preventable. And, of course, water supply is especially crucial in rural areas dependent on agriculture.

Mexican officials show off a recently installed photovoltaic water-pumping station on a ranch near La Paz, Baja California.

Where there is an abundant supply of water near the surface, say from a river, pumps can make it available for agricultural purposes. In other places, the water has to be brought up from wells hundreds of feet deep; in these cases, the supply is likely to be used for drinking and other living requirements. But it is often uneconomical to extend electric grids vast distances to serve poor, rural areas, which tend to have little political or economic clout. While locales where the twin problems of usable water shortage and lack of electricity are most acute tend to be mainly in developing countries, these problems exist also in the United States, with many in the Southwest, particularly on Indian reservations.

In places like this, solar power often seems to be the best solution. Abundant supplies of

sunshine can be used to generate electricity to run pumps and also to supply the myriad requirements of modern life. And, in fact, both research and commercial installations are rapidly proliferating around the globe.

International Sunlight

Sandia, for instance, has been involved since 1994 in bringing solar power to Mexico through its Mexico Renewable Energy Program, funded mainly by the U.S. Department of Energy and the U.S. Agency for International Development. So far, according to Michael Ross, program manager at Sandia, this project has led to the installation of more than 400 photovoltaic and small, wind-powered water-pumping systems, as well as other renewable energy applications, throughout the country; "98 percent are still functioning," Ross noted. Joint programs with the Mexican government are expected to bring as many as 1,200 new solar-power water-pumping systems (along with a few wind systems) to isolated areas in the next five years—and this does not include private-sector efforts along the same lines.

According to Ross, the electricity generated is not used just for pumping water. It allows children in rural hamlets to get an education by means of "telesecondarias," school courses provided via educational TV. It also powers bio-research stations.

tions, and
essions to
ans, and vendors with the operation and maintenance of the systems, so that the equipment can be sustained. The systems installed under the program are intended as pilot projects, which are meant to replicate themselves further under local initiative. "Thousands of systems have been replicated in the private sector from Sandia's originals," said Ross.

The arrays of photovoltaic panels produce direct current power. Most pumps in these rural applications, up to about 300 watts, run on dc. However, in some cases, the power must be converted to alternating current, as appliances and large pumps that run on dc are not readily available. The pumps are used to supply water for both agricultural and drinking purposes for a community. Sandia promotes the use of drip irrigation as much the most efficient way to bring water to crops. Tiny amounts of water are fed directly to the plants' roots, thus minimizing waste. Ranchers also need water for their cattle.

Former Philippine President Fidel V. Ramos tries out canal water pumped into a rice paddy by a solar pumping system as aides and WorldWater's Quentin T. Kelly (second from left) look on.

Ross emphasized that it was important to keep in mind the economic aspects of these projects. In the case of government-funded installations, costs are generally shared with the user; in other cases, the users pay for the systems themselves.

While photovoltaic systems are initially more expensive than diesel, sunlight, unlike diesel fuel, is free, and after about four years "the two graphs cross" as Ross put it, and PV becomes the cheaper option. PV systems also avoid the environmental problems of diesel units, such as pollution, fumes, and noise, as well as the need to transport the fuel. The PV installations, he said, are built to last for 20 years (with a new pump every few years), much longer than a diesel can be expected to last. In some places, Ross noted, wind power is an option, but that requires a good supply of wind, and windmills, being mechanical devices, are subject to wear.

Sunshine Goes Commercial

But solar power has moved far beyond being the exclusive realm of lab researchers and aid projects. Businesses large and small are rushing to cash in on what is suddenly starting to look like a major profit-making opportunity. For example, the multinational oil giant BP signed a $48 million contract on March 30 to bring solar power to 150 remote villages in the Philippines. According to the company, the project will serve a combined population of over 400,000. The electricity will power water systems in addition to home lighting systems, schools, hospitals, and other uses. This comes on top of the company's previous $30 million solar projects in Indonesia and the Philippines.

New, smaller companies are also active in the field. WorldWater Corp. of Pennington, N.J., began as an R&D and consulting firm in 1984 and is now operating in about 10 countries around the globe. As Quentin T. Kelly, chairman and CEO of WorldWater, put it, the firm combines the functions of water engineering and solar engineering, locating suitable water sources and installing solar-powered pumping systems. The company often figures out how to arrange financing, too.

The heart of the company's systems is a patented controller that Kelly refers to as the "brain." Anand Rangarajan, a structural engineer who is executive vice president of World-Water, explained that the dc power from the photovoltaic array is fed into the brain, where it is converted to a variable-voltage, variable-frequency ac signal that can be fed to standard, off-the-shelf pumping equipment.

The brain, which Rangarajan called the company's "core technology," regulates this variable flow of electricity, taking what power is available from the solar panels—less in the morning, say, or on a cloudy day, more in bright sunshine—and matching it up to the pump, thus extracting as much energy as possible from the panels. Care is taken not to exceed safe operating limits. The pumps can operate unattended, turning themselves on and off every day. The controller also shuts down the pump if it starts running out of water. Kelly says of the pumps, "We never burn 'em out," even though voltage can jump from 160 to 600 V in seconds.

In this surreptitiously taken photograph, a welcoming committee from the Moro Islamic Liberation Front meets WorldWater personnel outside the guerrillas' mountain camp in Mindanao.

He added that this ability to match a variable stream of power to the pump means "we can use anyone's pump," rather than having to use dc motors or special variable-voltage ac motors, which tend to be expensive and in short supply in Third World islands and deserts and similar places. For a solar installation, there is a lot of power in that stream. Rangarajan said that WorldWater's electronics allow its systems to yield up to 50 horsepower. Kelly claimed that this lets the company use pumps giving flow rates up to 2,000 gallons per minute.

Such rates are for localities where water is found at or near the surface. Often, this water will not be clean enough to drink, but fine for irrigation. In drier areas, it may be necessary to dig deep wells to find potable water, and it may be too expensive to use for agricultural purposes.

Some of the company's activities take it into somewhat dicey territory. In the Philippines, the government asked the company to install a solar pump at a headquarters of the rebel Moro Islamic Liberation Front on the island of Mindanao, as a goodwill gesture during some attempted peace negotiations. Kelly and his aides "trekked through jungle, leeches, and mud" to meet the rebel chieftains, and the pump was successfully installed. When the army overran the base some time later, the pump was still in working order.

Kelly has also been talking with the new government of Somalia, which is still in the throes of seemingly endless civil war, and the company has also been active in Ethiopia and Angola.

Some of the company's more ambitious activities have been in the Philippines, notably on the island of Cebu, where "people were paying a lot for water," according to Kelly, and where waterborne illness was a problem. The U.S. Trade and Development Agency partly financed a study of the feasibility of solar power, which led to a multimillion-dollar contract to bring electricity and water to 40 municipalities and 200,000 people. According to Kelly, this is the initial phase of a larger project. Many of WorldWater's

projects are still in the planning or construction phase, but one of these projects, at Nug-as, is already in operation, and six to eight more are scheduled to debut in the next few months.

Kelly related how, a year and a half ago, he had just signed a $50 million memorandum of agreement with Pakistan's Prime Minister Nawaz Sharif to deliver power and water to 8,000 villages in the Baluchistan region. Within weeks, Sharif's government was overthrown by the army. In a month, Kelly was back in Pakistan talking to the new military leader, Gen. Pervez Musharraf, who said Kelly was "the first American who's dared to come see me."

The general reaffirmed the agreement and asked Kelly to prepare a national electrification and water supply program. This plan was recently approved by Musharraf's government, and so Pakistan, at least in its rural areas, has adopted solar power as its mainstream power source. According to Kelly, this gives his company what is potentially its largest solar contract ever, worth approximately $150 million to start.

Recently, a crisis has arisen in Pakistan's Cholistan desert, where surface water has dried up, leaving the local people, pastoralists who live by herding cows, wandering around looking for water to keep themselves and their 2 million cows from dying. WorldWater was called in to deal with this emergency, but on drilling found that the water available at 150 to 180 feet was brackish; that is, it was slightly salty. It was necessary to go down an impractical 1,000 feet to find fresh water. Since desalination is too expensive, cows and people will have to make do with water from the least brackish wells.

A desert village in Pakistan is one of the recipients of water supplied by solar-powered pumping systems. The canister at left supplies dozens of huts.

Kelly mentioned that studies were in progress at Rutgers University in New Brunswick, N.J., to investigate the use of brackish water in irrigation. Certain types of plants can tolerate a degree of brackishness. In parts of Cholistan where underground lakes of brackish water have risen near the surface, Kelly plans to bulldoze off the surface and use the resulting ponds to grow fish in the desert. Tilapia are said to tolerate the prevalent brackishness well.

Another prospect for WorldWater is in Sri Lanka, where the company expects to receive a $17.3 million contract to bring electricity to several hundred fishing villages in the southern part of the island. In addition to providing clean drinking water and electricity for household use, as well as for hospitals and the like, the Sri Lankans are interested in the company's solar lantern technology, which can provide five hours of illumination after being charged with sunlight. According to Kelly, "One in a hundred fishing boats burns from kerosene," which the fishermen now use for light on their nighttime forays, so

solar-charged lanterns should be welcome.

Sunlight in the Mirror

Other approaches to solar power being pursued include the Department of Energy's Concentrating Solar Power Program. It funds projects in solar-thermal technologies, where in place of the usual silicon wafers, mirrors are used to focus sunlight on a point.

A group of Sandia researchers is working with several southwestern tribes to test prototypes of a technology that involves using the focused energy from mirrors arranged in a parabolic dish formation to drive a Stirling engine; this in turn can be used to generate electricity. An advantage of this system is that it produces ac power directly, obviating the need to convert from dc. The objective, according to Rich Diver, project manager for advanced dish development systems, "is to develop a dish Stirling system for water pumping," an objective chosen because "every tribe we asked identified that as the major need." The technology is expected to be of most benefit overseas. The first prototype, with its 500 square feet of mirrors, is already in operation at Sandia. Diver was scheduled to deliver a paper on the advanced dish development project at Solar Forum 2001 in Washington, D.C., in late April.

In a village in Tanzania, WorldWater's Michael Ingles instructs villagers in how to install a solar pump. The village had been without fresh water for three years after a diesel pump broke down.

The system includes a Solo 161 Stirling engine from the German firm Solo Kleinmotoren hooked up to an electric generator, in addition to the mirror array. The sunlight is concentrated on the engine's heater tubes, filled with high-pressure helium. The helium expands, driving pistons and producing mechanical power that in turn drives the generator. The electricity produced is again of variable voltage, which drives the pump at variable speed. This system, too, operates automatically, turning itself on and off and responding to conditions as needed.

Of course, without a supply of water there will be nothing to pump. Emphasizing the need for water conservation, Kelly observed that only 3 percent of the water on Earth is fresh and, of that, half is locked up in glaciers. This leaves 1 1/2 percent, but half of that is contaminated. Thus, only 3/4 percent of the world's water is usable for drinking or irrigation.

By 2025, Kelly said, there will not be enough water available on the planet. Like Sandia's Ross, he advocates drip irrigation, as well as water management programs. The important thing, Kelly emphasized, is to foster the awareness that the Earth's water supply situation is a crisis.