Oregon Solar Electric Consumer's Guide

Remote Water-pumping Systems

Oregon Office of Energy
625 Marion St. NE, Suite 1 • Salem, OR 97301-3742
1-800-221-8035 • www.energy.state.or.us

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Oregon Solar Electric Consumer's Guide — Remote Water-pumping Systems, February 2001 Edition
Justin Klure and Christopher Dymond, Oregon Office of Energy

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Remote Solar Water-pumping Systems

One of the best uses of solar electric systems is to power water pumps in remote locations far from utility lines. Photovoltaic (PV)-powered systems offer simplicity, reliability and low maintenance for a broad range of applications. They are used to pump water for livestock, wildlife, small-scale irrigation and homes off the traditional power grid. In remote locations where power line extensions are too expensive, solar systems are often the least-cost solution.

Powering a remote water pump

A remote water pump may be powered by extending the existing power line, wind power generation, a gasoline generator or a solar PV system. Extending the power grid is usually too expensive to be cost effective. Wind power may be a viable option if there is significant summertime wind (9–12 mph) and the pump and/or tank location remains fixed. Gas generators are commonly used but have high fuel costs and require regular maintenance and numerous refueling trips. Solar electric (PV) systems are highly reliable, need no refueling visits, require minimal maintenance and can be easily relocated.

If your location receives sunlight during the time of year the water is needed, solar may be your best option. Watering seasons usually occur from early spring to late fall, when most of the state receives plenty of sunlight.

Figure 1.—Solar-powered stock watering.

The solar alternative

The three main power source options for remote pumping include: wind turbines, gas generators and solar photovoltaics.

Windmills can be used on ranches to provide water for livestock. However, you need ample and regular wind resources. Also, wind often does not blow as much in the summer when livestock need the most water. Other drawbacks are that windmills require significant maintenance and seals on the well plunger assemblies must be replaced regularly. In addition, service personnel (usually the rancher) must climb the windmill tower periodically.

Combustion engines are used most often but require significant maintenance including regular oil changes and tune-ups. They also require expensive fuel, which contributes to the high operation costs. Gas generators require fuel to be hauled to the pumping site, are noisy and give off unpleasant exhaust fumes.

In contrast, PV pumping systems are quiet, need no fuel, require very little maintenance and pump the most water during the sunniest, hot days of summer. PV pumping systems are becoming more popular because of their low maintenance requirements and high reliability.

Other advantages include:

"Free" energy — Once a PV system is purchased and installed, there is no additional cost for fuel. Sunlight is a renewable and plentiful resource throughout most of Oregon. A solar system can offer protection against rising fuel costs.

Reliable power — PV power supplies have no moving parts and the PV modules carry 20- to 25-year warranties. Minimal maintenance is required. For these reasons, PV systems have become the power source of choice for many critical applications such as military operations and emergency stations.

Flexibility — Many PV pumping systems allow for convenient expansion or relocation. If the pump is large enough to accept additional power, PV modules can be added later to increase water output for seasonal operation. Solar pumping systems can be used as a grazing management tool providing greater control over your grazing areas.

Quick installation and portability — Most PV water-pumping systems can be installed in less than a day. Because they are easy to install, they can be moved from one water source to another to serve different livestock or encourage relocation of livestock. In fact, some ranchers have installed their PV systems on trailers to move them quickly to where the water is needed.

Before purchasing a PV pumping system, take the time to accurately estimate water requirements. Unlike line-connected pumps that deliver water on demand, most PV pumping systems deliver water only when the sun is shining. This means you need a larger water storage facility to provide water during the night and other times when the sun is not shining.

Cost comparisons

The table below compares the cost of installing and operating a remote water pumping system with a line extension, a diesel generator and a solar photovoltaic system of approximately 160 watts. A system of this size operates a pump capable of pushing 3.5 gallons per minute, or up to 1,500 gallons per day, during peak summer hours.

Cost Comparisons — 160-watt Solar Water-pumping System

	Line Extension	Diesel Generator	PV System
Installed costs	$10,000 (1 mile)	$ 1,300	$3,100
Equipment life	30 years	15 years	20 years
Annual costs			
Maintenance	$ 500	$ 100	$ 25
Energy costs	$ 32	$ 250*	$ 0
Total operating costs	$ 532	$ 350	$ 25

PV system savings and payback (compared with diesel)

Additional cost of PV system	$ 1,800
35% Business Energy Tax Credit	$ 630
Additional cost after tax credit	$ 1,170
Yearly savings on maintenance and fuel	$ 325
Simple payback (1,170/325)	**3.5 years**

**Figure based on 180 gallons throughout the watering season at $1.50/gallon.*

Solar Water-pumping System Components

Most PV-powered pumping systems consist of a PV array, a water pump, a pump controller and water level sensors or float switches.

PV array

The PV array is composed of PV modules that range in size from 50 to 120 peak watts and cost from $250 to $600 apiece. The PV modules are the most reliable component in any PV pumping system. They have been engineered to withstand extreme temperatures, severe winds and impacts from one-inch hail balls. Some are even designed to perform when they've been vandalized by gunshots. PV modules have an expected life expectancy of 25 to 30 years and the manufacturers warrant them against power degradation for 20 to 25 years. PV modules require no care other than occasional cleaning of the surface if they are used in dusty locations.

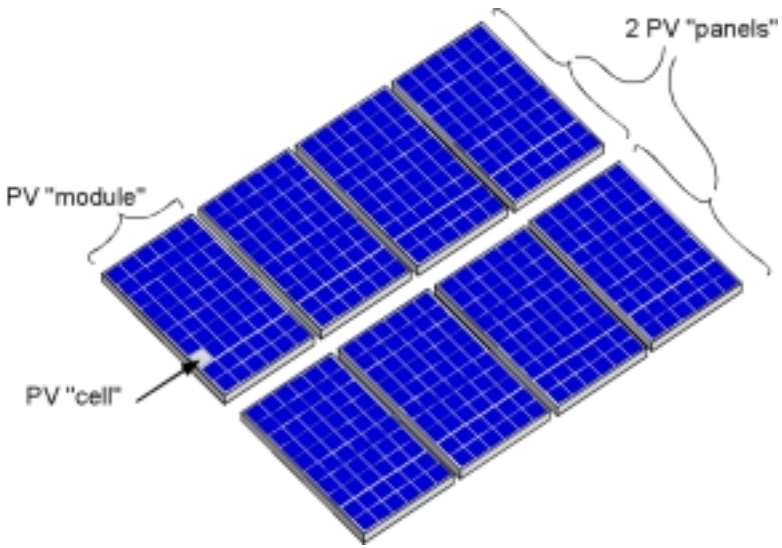

Figure 2.—A PV array is composed of one or more panels.

For simplicity, locate the array close to the well to keep wire runs to a minimum. Fencing may be required to protect the array from animals in stock watering applications. In some cases, Fish and Game and/or the Forest Service might help offset the cost of fencing. A good ground is required — many pump systems are struck by lightning. A ground can be made to the well casing or wellhead.

Water pumps

The main difference between conventional line-connected pumps and PV pumps is the fact that PV pumps are designed to run off of Direct Current (DC) power supplies. There are many reliable DC pumps designed to operate with PV power supplies. Alternating Current (AC) pumps also are being developed that can operate from DC power supplies. If extensive pump maintenance is required, an AC pump might be your best option. A specific type of charge controller capable of inverting the power is required for an AC pump. There are two basic classifications of pumps — centrifugal and positive displacement. These pumps are also available in both surface and submersible models.

Centrifugal pumps are the most common type of pump and can handle 5 to 15 feet of vertical lift. Pump efficiency quickly decreases with increased head. Centrifugal pumps move water by means of blades or impellers that rotate at high speeds. Because the movement of the water depends on the force created by the impeller, both the water flow rate and vertical lift capability are related to the speed of the impeller and pump motor. Therefore, a centrifugal pump might fail to deliver water if there is a significant decrease in the power supply (e.g., a cloudy day or an increase in the pumping head).

To their advantage, centrifugal pumps have no seals or mating surfaces to wear out, are fairly tolerant of dirty water and typically

Figure 3.—Centrifugal pump.

Courtesy of Dankoff Solar

Courtesy of Dankoff Solar

Figure 4.—Positive displacement pump.

require no regular maintenance. In general, centrifugal pumps are good for pumping medium to large volumes of water at low to medium heads. Centrifugal surface DC pumps start at around $600.

Positive displacement pumps move water by mechanically advancing a sealed quantity of water. Some of the more common positive displacement pumps used with PV power supplies include diaphragm, piston and jack pumps. A positive displacement pump's flow rate is directly related to the motor speed and power input. But in contrast to centrifugal pumps, its vertical lift capacity is relatively unaffected by motor speed. This means that PV-power positive displacement pumps are more likely to pump water under low light conditions although at a slower rate.

Since all positive displacement pumps have seals, mating surfaces or diaphragms, they require regular maintenance to replace or repair worn parts. In general, positive displacement pumps are good for pumping small to moderate amounts of water at all heads. Positive displacement DC pumps start around $1,000.

For livestock watering applications, submersible pumps are by far the most popular. This is because they can be used in both wells and surface water supplies and they are much easier to protect from freezing.

Submersible diaphragm pumps typically deliver as much as 1,500 gallons per day and have a vertical lift limit of about 200 feet. The largest diaphragm pumps can accommodate up to 3,000

gallons per day and up to 800 feet of vertical lift. Prices for solar DC diaphragm pump systems start around $1,200.

Submersible centrifugal pumps are used in medium to large PV pumping systems. They can deliver as much as 40,000 gallons per day and have vertical lifts of up to 600 feet. Systems with these capabilities require very large PV power supplies and might not be cost effective for most applications. Typical submersible centrifugal systems start at around $2,000. Centrifugal systems can be designed to be as cost effective as any other PV pumping system.

Pump controller

Figure 5.—Pump controller.

A pump controller (current booster) is an electronic device used with most solar pumps. It acts like an automatic transmission, helping the pump to start and not to stall in weak sunlight. Pump controllers maximize the water delivery of pumps by matching the voltage and current output of the PV array to the requirements of the pump motor, thus allowing the pump to operate in low light conditions.

Some controllers also contain features to protect pumps from power surges, over current, overheating and dry run conditions. They also accept input from water-level sensors and float switches to prevent pumps from running dry or to stop the flow of water to a tank once it is full.

Solar trackers

Array tracking is recommended for most PV water-pumping systems to increase the pumping time and production of water. Trackers optimize the energy production of PV modules by directing them toward the sun as it travels across the sky. They can increase the water supply by as much as 20 percent. Not only do trackers increase energy production, but they also can reduce

Figure 6.—Solar tracker.

the need for more panels. Passive trackers with few moving parts and no motor or controls can support up to 16 PV modules.

However, trackers with even just a few moving parts add to the complexity of a pumping system and can increase the cost. As a general rule, trackers do not gain enough energy during the winter months to pay for their added expense. However, if your water requirements are highest in the summer, a PV pumping system with a solar tracker might be your least expensive option.

Average wind velocities must be taken into account when considering the use of tracking support structure. Wind velocities above 25 mph can prevent tracking if a passive, freon-driven tracker is used. Support structures should be aluminum or galvanized or stainless steel designed for maximum anticipated wind velocities. In high-wind locations, you might need to consider active, motorized tracking.

Storage tanks

Regardless of the type of pump used, water usually is stored in a tank or reservoir and gravity-fed to the watering site. Most pumping systems do not include batteries for on-demand water. For stock watering applications, round, open tanks of galvanized steel with steel, cement or clay bottoms typically are used. In most cases, the water storage or tank should be large enough to provide water through a minimum of five days of cloudy or overcast weather. For instance, if a rancher needs 1,000 gallons per day to water 50 head of cattle, he or she should have a water tank that holds a minimum of 5,000 gallons.

Sizing a Solar Pumping System

The size of the solar power system depends on water demand, vertical lift and efficiency of the pump system. To determine whether the energy required to pump the necessary amount of water can be cost-effectively supplied by a PV system, you need to know the following:

Total pumping head

Total pumping head is calculated by measuring the total change in elevation from the water level of the well to the top of the storage tank (assuming the water is gravity-fed to the water site).

Water requirement

Water requirement is calculated either in gallons per day (GPD) or gallons per minute (GPM). A typical cow will drink 10–30 gallons per day in the summer months.

Season of use

The time of year determines the solar resource for a particular region.

Site location

Determining where the site is located and the water source you are drawing from will provide the necessary information for the pump selection and the amount of solar power needed.

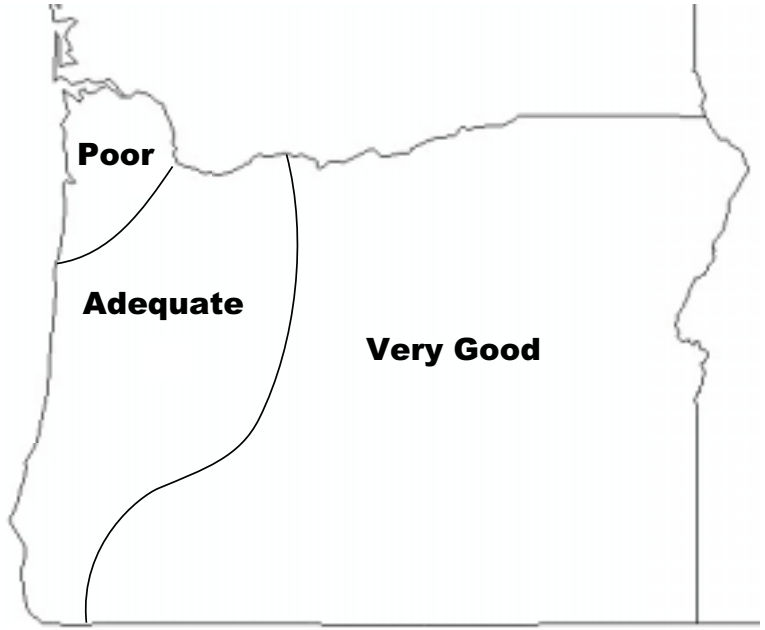

Figure 7.—A general overview of Oregon's solar resource. Anywhere east of the Cascades has ample sunlight to power a solar water pump during the summer season and possibly throughout year. The areas on the west side of the mountains have variable sunlight, yet still are appropriate for summertime loads. For more specific information regarding your location and the potential sunlight, call the Oregon Office of Energy (1-800-221-8035).

Solar Water-pumping Cost Estimates

The pumping head and water requirement together determine the amount of energy required to relocate the water. The season of use and location determine the amount of sunshine available to supply the required energy. If the energy requirement is too high or if too little sunshine is available during a season of high use, the cost of a PV system large enough to provide the energy will be unreasonable, even in comparison to a long line extension. To calculate the solar power needed for a particular system, solve the following equation:

$$\text{PV WATTS} = \frac{\text{LIFT(FT)} \times \text{GPM} \times 18.8}{40} \times 1.25$$

The typical cost for PV panels is about $5 per watt (not installed). Multiply your answer from the above equation by $5 to get a general estimate of what your PV panels will cost. Other estimated costs include: $300–400 for a controller, $600–800 for a tracker, $100–200 for wiring and mounting fixtures, and $600–3,000 for pumps.

Selecting a vendor

Once all of the necessary site data is collected and verified and the site is determined to be appropriate for a PV-powered system, it's time to select a solar vendor and/or supplier. Careful consideration should be given to your choice of system supplier and their experience in designing and supplying PV systems. PV systems can be designed and installed to provide decades of safe, reliable service. Systems not designed or installed in a safe manner could result in fire or personal injury. The PV system supplier you choose should design PV pumping systems to comply with the National Electric Code. Contact the Oregon Office of Energy for a list of vendors in your area.

Oregon Programs and Incentives

The Oregon Office of Energy offers tax credits, cash rebates[1] and technical help for solar electric (photovoltaic) systems for water pumping in remote areas:

- ☐ 35 percent Business Energy Tax Credit on additional cost of the photovoltaic system. Tax Credit applications must be pre-approved before system purchase.
- ☐ Over-the-phone application process with fees waived.[1]

☐ $100 cash rebate[1] upon project completion.
☐ Professional staff to help review system sizing and equipment specifications.

[1]*Cash rebates and no-fee applications are limited. Funds will be disbursed on a first-come basis through September 2001.*

Program steps

1. Call the Oregon Office of Energy (1-800-221-8035) to start the tax credit application over the phone and to get help locating local vendors. The Oregon Office of Energy can assist you in sizing your system to meet your needs. Please be prepared to discuss some of the information in the picture below regarding your project.
2. Get a vendor quote for equipment and installation costs.
3. Return signed Business Energy Tax Credit (BETC) application sent to you by the Office of Energy.
4. Install the system.
5. Send Office of Energy proof of completion and details of the total cost.
6. Receive tax credit certification and $100 rebate check.

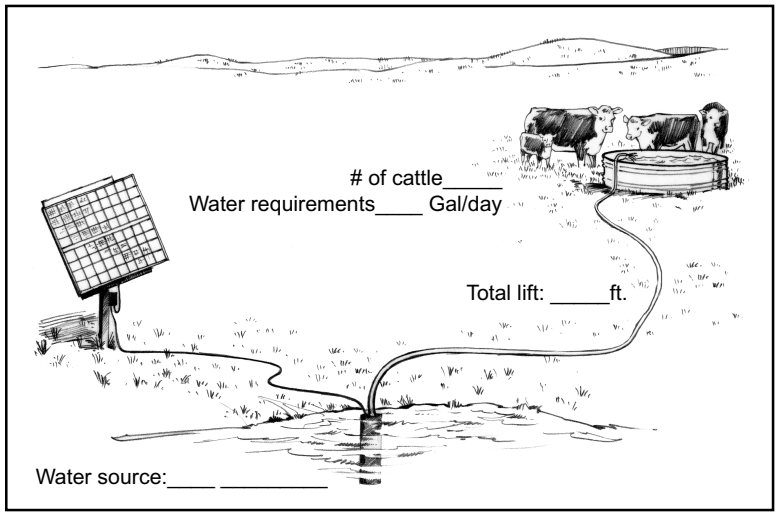

Figure 8.—Sizing a solar system.

Solar water-pumping systems are the least-cost option for remote watering applications and are far cheaper to own and operate than a diesel or gas generator. The additional cost of the photovoltaic system can be recaptured within the first few years of operation from fuel cost savings alone. PV water-pumping systems require no refueling visits and minimal maintenance, and they're expected to last at least 20 years. They also can give you greater control over your grazing areas. PV pumping is another way you can help improve Oregon's environment while increasing your bottom line.

For more information, contact Justin Klure or Christopher Dymond, Oregon Office of Energy, 625 Marion St. NE, Salem, OR 97301-3742; 1-800-221-8035; Fax (503) 373-7806.

Case Studies: Solving Problems Using Photovoltaic Water Pumping

Some Oregon ranchers have found that solar-powered water pumping is a cost-effective way to give their cattle a drink.

Skinner Ranches Inc. in Jordan Valley, for example, needed power at a remote well to water cattle. A feasibility study showed a solar photovoltaic (PV) system to be cheaper over its lifetime than running a power line to the well or installing a generator. The system was even cheaper with a 35 percent Business Energy Tax Credit offered by the Oregon Office of Energy.

Other ranchers are discovering that PV systems, which use silicon panels to convert sunlight to electricity, have benefits beyond being cost-effective and reducing fossil fuel use. They can serve as creative solutions to challenges a ranch may have because of its location or land base.

Tromp van Holst: Keeping streams clean with PV

The problem

Martin and Melanie Tromp van Holst are Cove-area cattle ranchers in eastern Oregon concerned about water quality. They knew that using a PV water-pumping system to keep cattle out of streams would protect riparian zones, helping to keep soil, vegetation and fish habitat healthy. But they wondered whether solar power would also be a cost-effective solution for keeping polluted groundwater out of streams. Groundwater contaminated with fertilizer nitrates flows from nearby property onto the Tromp van Holst ranch and into the Grande Ronde River. The family wanted to use PV pumping to grow a forest that would serve two purposes: be a marketable crop and soak up the nitrates and other nutrients before they reached the river.

The solution

The Tromp van Holsts planted several acres of fast-growing hybrid poplar saplings that could serve as a buffer between the polluted groundwater and the river. The Tromp van Holsts needed to irrigate the poplars with river water. They chose a 240-watt PV system to power a pump capable of distributing about 270 gallons of water per hour through a drip irrigation system. The PV system was estimated to be cheaper than either a power line extension or a generator.*

Richard Cockle

Figure 9.—Photovoltaic-powered drip irrigation system.

The result

The Tromp van Holsts' 14-year-old son manages the tree plantation and the PV system. The family is finding the PV system to be reliable, cost-effective and low-maintenance. Once the trees are established, the portable PV system can be moved to help start another plantation. When the trees are mature, researchers will determine how the poplars soaked up nitrates and other nutrients from the groundwater. The Tromp van Holsts plan to sell the mature trees for firewood to help pay for their son's college education.

Hotchkiss Ranches: A fragile ecosystem

The problem

Before Mark and Susan Doverspike installed a PV system, thousands of remote arid acres went under-used at Hotchkiss Ranches, their fourth-generation ranch in Burns. The problem was too little accessible water for 500 head of cattle, despite a wetland spring in the area. The spring had been fenced off because cattle overused the wetland when they came to drink. The Doverspikes wanted to pump water from the spring to cattle troughs in a less sensitive area three-quarters of a mile away (and 40 feet higher in elevation).

The solution

Extending a power line six miles to the spring would cost about $60,000 up-front and $500 in annual maintenance . The 160-watt PV system they installed instead cost only $2,800. Maintenance costs are less with the PV system, too, and there are no electricity bills. Gas and diesel generators also would have been more expensive over the equipment's lifetime than a PV system (see table on next page).

Cost Comparisons — 160-watt System for Hotchkiss Ranches

	Line Extension	Gas Generator	PV System
Installed costs	$60,000 (6 miles)	$1,300	$2,800
Equipment life	30 years	15 years	20 years
Annual costs			
Maintenance	$500	$100	$25
Energy cost	$32 ($.045/kWh)	220 (180 gal. x $1.20)	0
Total operating cost	$532	$320	$25
PV System Savings and Payback (compared with gas)			
Additional cost of PV system		$1,500	
Oregon Office of Energy rebate		**$100***	
35% state Business Energy Tax Credit		**$490****	
Additional cost after rebate and tax credit		$910	
Yearly cost savings on maintenance and fuel		$295	
Simple payback ($910/$295)		**3 years**	

*While funds last, a $100 state rebate is available if the PV system costs less than a power line extension.
**Typical tax credit for a project with an incremental cost of $1,500. Hotchkiss Ranches did not receive a tax credit or state rebate because the Oregon Office of Energy paid for the PV system as a demonstration project.

OSU Extension Service

Figure 10.—Ranch owner Mark Doverspike (right) and Justin Klure, Oregon Office of Energy, by the pump and wetland spring that provide water for 500 head of cattle at Hotchkiss Ranches, near Burns.

The result

The PV system at the Doverspikes' ranch is designed for a maximum pumping rate of 3.5 gallons per minute. Floats on the troughs monitor water level, keeping them from overflowing. The Doverspikes worried that vandals might use their solar panels for target practice, but no problems have occurred. Even if someone had shot the panels, the Doverspikes chose a model designed to withstand such vandalism.

The system provided an added bonus beyond cost savings and habitat protection: The PV pumping system provides a water source for elk and other wildlife that also drink from the troughs.

Photovoltaic water-pumping system at Skinner Ranch

The Oregon Office of Energy helps ranchers afford solar photovoltaic (PV) water-pumping systems with a 35 percent Business Energy Tax Credit toward added equipment and installation costs.

PV systems, which use silicon panels to convert sunlight into electricity, have proven cost-effective in remote locations where it's expensive to run power lines. They also are reliable and environmentally friendly. Besides saving fossil fuels, PV water pumping systems help protect the health of riparian zones — areas alongside streams. When cattle are free to drink in streams, fragile soil and vegetation are destroyed and streambeds are damaged. Water temperatures rise — endangering fish — and the water becomes polluted with manure and silt. By pumping water from streams or wells into storage tanks away from streams, ranchers can protect riparian zones while providing water for their cattle.

PV system was the least-cost option

In the fall of 1990, Skinner Ranches Inc. asked Idaho Power to examine alternatives for supplying power to a well used for watering cattle. With the ranch 80 miles south of Ontario on the Oregon-Idaho border, the estimate for running a power line to the well was $40,000 to $45,000. Idaho Power conducted a feasibility study on a solar PV system for the ranch. Not only was it determined to be technically feasible, but with a price tag of $34,000, it was significantly cheaper than the power line. Based on the estimated life of the systems analyzed, the PV system also would cost less than a diesel generator (see table).

Figure 11.—Photovoltaic arrays and holding pond on the Skinner Ranch.

The Skinners decided to go with the PV system, and by the summer of 1991, their solar-powered system began pumping water.

How it works

The PV system on the Skinner Ranch is designed to pump up to 10,000 gallons of water per day during the summer months for 600 to 800 head of livestock. The pump can deliver up to 18 gallons per minute on a full day of sunshine. The electricity powers the pump and charges batteries, which supply power to the pump when the sun isn't shining. When there's not much sun and the batteries are depleted, a sensor calls for the backup propane generator to take over pumping. A low-water alarm can be installed as a precautionary measure in case of sensor or pump failure.

Water is pumped into a 60,000-gallon holding pond, sized to ensure ample water supply for the herd. The holding pond is surrounded by a nine-foot chainlink fence to keep out cattle and other animals. The water flows by gravity to watering troughs.

The benefits

For the Skinners, the PV system has proven cheaper and more reliable than other water pumping systems. It also has reduced environmental impacts and resulted in more efficient use of resources. Any overflow from the holding tank is channeled outside the fence to a pond for wildlife.

The economics

While the initial cost of the Skinners' PV pumping system was much lower than that of a power line, it was higher than the initial cost of a diesel generator (see table on next page). However, because PV pumps require little maintenance and use no fuel, they are far less expensive to operate than diesel-powered systems. In fact, over their lifespans, PV systems cost as much as 50 percent less than diesel systems.

The table below compares the costs of a power line extension, a diesel generator and a PV system for the Skinners. It also shows how the Business Energy Tax Credit reduced the costs and payback for the PV system.

Cost Comparisons — 2-Kilowatt System for Skinner Ranch

	Line Extension	Diesel Generator	PV System
Installed costs	$40,000 (4 miles)	$15,000	$34,000
Equipment life	30 years	15 years	20 years
Annual costs			
Maintenance	$1,000	$1,400	$1,000
Energy cost	$2,500 ($.045/kWh)	$1,900 ($1.20/gal diesel at time of project)	$0
Total operating cost	$3,500	$3,400	$1,000
PV System Savings and Payback (compared with diesel)			
Added cost of PV system		$19,000	
35% Business Energy Tax Credit		$6,600*	
Yearly cost savings		$2,400	
Additional cost after tax credit $12,400			
Simple payback with tax credit		5.2 years	

*Typical tax credit for a project with an incremental cost of $19,000. The actual tax credit for the Skinner Ranch project was higher. Because the Skinners' PV water pumping system was a state demonstration project, they received a tax credit on the entire cost of the system — not just the added cost.

Other Programs and Organizations

U.S. Dept. of Energy's "Million Solar Roofs" program

This program supports funding for several activities around the state that support market development of photovoltaics, solar water heating and transpired collectors. This program does not provide money for equipment; however, it does help communities and groups identify barriers and take steps to reduce barriers for solar markets.

Oregon Solar Radiation Laboratory

For information about the solar energy resource for your area, contact Dr. Frank Vignola of the University of Oregon, (541) 346-4745.

Solar Energy Association of Oregon

SEA of O is a nonprofit chapter of the American Solar Energy Association. SEA of O provides public education and outreach about the benefits and uses of solar energy for space heating, water heating and electricity generation.

Solar energy Web sites

Nontechnical

Oregon Office of Energy
www.energy.state.or.us

Dankoff Solar Products
www.dankoffsolar.com

Wind and Sun
http://www.windsun.com/water/Water.htm

Sol-tec Systems
http://www.solar-tec.com/SolarWaterPumping.htm

Oregon Solar Energy Industry Association
www.seia.org

Solar Energy Association of Oregon
www.solaror.org

Utility solar information
http://www.westernsun.org/
University of Oregon Solar Information Center
http://darkwing.uoregon.edu/~sic/
Home Power Magazine
www.homepower.com
Sandia National Laboratory
http://www.sandia.gov/pv/main2.html
US DOE Million Solar Roofs
http://www.eren.doe.gov/millionroofs/
PV system energy calculations
http://rredc.nrel.gov/solar/codes_algs/PVWATTS/

Technical

US DOE PV Program
http://www.eren.doe.gov/pv/
University of Oregon Solar Monitoring Lab
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Sandia National Laboratory
http://www.sandia.gov/pv/main2.html
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