# ELECTRICITY WHEN AND WHERE YOU NEED IT: FROM THE SUN

## PHOTOVOLTAICS FOR FARMS AND RANCHES

# Introduction

Solar-generated electricity, first used for satellites in space, now makes economic sense on farms and ranches. In the case studies presented here and in many more like them across the country, photovoltaics (PV) is the cheapest and most reliable way to get the job done.

When sunlight strikes the surface of solar cells, a flow of direct-current (dc) electricity is generated that can perform many important jobs. Wires transmit this electricity directly to power equipment or to storage in batteries. Solar modules or panels (composed of many interconnected cells) can be connected in series or in parallel to run small motors, lights, or other electric loads. An inverter can be added to convert dc power to alternating current (ac) for running ac equipment. Some of the PV systems described here have been operating reliably on farms and ranches for 6 years or longer. Warranties of 10–15 years come with most solar-electric modules today. And because

# Table of Contents



| | Outbuildings/Homes | Vehicles |
|---|---|---|
| PUMPING | domestic water | |
| BUILDINGS | outdoor security; indoor task lighting; ventilation fans | |
| RANCH | | keep batteries charged |

they have no moving parts, maintenance of modules is limited to visual checks and an occasional cleaning. PV panels also produce power in all types of weather. On partly cloudy days they produce up to 80% of their maximum output, and even on extremely overcast days, they can still produce about 25% of their maximum.

In this booklet, farmers and ranchers describe their experiences using PV to pump water, to supply power to buildings, and to operate labor-saving equipment far from utility lines. For each case study, we include system costs, specifications, and someone you can contact for more information. In addition to the case study accounts of actual installations, we include photos of related projects and basic information about buying, designing, and installing PV for farms and ranches.

| Fences | Fields | Yards | RV/Trailers | Crop storage | Livestock |
|---|---|---|---|---|---|
| | wells, ponds, streams | wells, ponds, streams | | | wells, ponds, streams |
| marker lights | | security and task lighting; entrance signs | security and task lighting; battery charging | security and task lighting; ventilation | security and task lighting; ventilation |
| electric fences; invisible fences | supplement feeder/sprayer; sprinkler controls | compressor for fish farming | battery charging | fans for crop drying | supplement feeder/sprayer |

# PUMPING WATER

USING PV TO PUMP WATER makes sense on farms and ranches.

*It is often cheaper than the alternatives.* Installing a PV pumping system is often cheaper than running a new power line if the well is one-quarter mile or more away from the main power line.

*It can go where the need is.* More and more ranchers want portable pumping systems that can be moved along with the cattle to new pastures.

*The more sun, the more water.* The sunniest days that generate the need for water also produce the most electricity from a PV system.

*Systems are easy to install.* PV pumping systems can be connected to existing wells and pumps or installed quickly in new wells. The technology is easy for most well and drilling contractors to apply.

PUMPING WATER

# A Portable PV system pumps well water

*John Buol Feeding Company, Burlington, Colorado*

## How it works

A PUMP JACK POWERED BY PV can replace a broken windmill. The PV panels power a dc electric motor to move the pump jack mechanism up and down. When the trailer with PV, electric motor, and pump jack is pulled up to the well, the sucker rod from the cylinder pump is attached to the jack with a wire cable coupling. Setting up the system takes about 10 minutes, once the trailer is backed into place. For local conditions, the angle of the PV panels can be adjusted. A portable stock fence is set up around the unit to protect it from the cattle.

RICK HINRICHS, BOULDER, COLORADO

*It took these ranch hands about 20 minutes to reconnect John Buol's PV pumping system late this spring. The system will pump water for his cattle that graze this leased pasture all summer. The system can be moved to another pasture when the lease is up.*

## How it came about

Moving cattle from one section of leased pasture to another is becoming a popular way to raise beef. Stock owners like John Buol in eastern Colorado are always looking for better ways to get water to these thirsty herds.

In times past, landowners here dug wells and installed windmills to water their cattle. Later, they plowed the land for wheat and ignored the unneeded windmills. In going back now to grass and cattle, the wells are still good, but most of the windmills are ruined.

When John Buol leased a pasture near the Bonny Reservoir, he talked to driller Wayne Parrish about using solar to pump water from an old well next to a fallen windmill. Buol couldn't see fixing up the windmill because he might not lease the land the next year. He wanted a system he could move to other wells in future years.

As the local drilling contractor, Parrish had been working with PV-powered pumping systems for a few years.

"I watched it for a long time before I ever touched it," Parrish confesses, "and my first experiences with solar were disasters. We purchased these little diaphragm pumps that are pretty viable

## Table of System Specifications

| | |
|---|---|
| Rated power: | 340 watts |
| Operating voltage: | 90 volts dc |
| Storage: | No batteries; stores water in tank |
| Total cost of PV trailer and pump jack: | $5,000 |
| Estimated cost for utility connection: | $10,000 per mile from utility power |
| Maintenance: | The system sits out all winter without problems |

## Contact about case study

Parrish Drilling
45985 Road Y
Burlington, CO 80807
Wayne Parrish: 719-346-7395

in shallow settings, but from our depth — 160 feet or greater — they just don't do the job."

But Parrish liked the idea of solar. "I decided that the concept was good. You just need enough power for the job." He has gone on to install many successful PV-powered submersible pumping systems for deep wells, and he provides the diaphragm pumps for shallow pumping jobs.

For John Buol's needs, Parrish assembled a simple portable system at his shop during the winter. "Putting a dc motor on a pump jack, something that we are already familiar with and use regularly, was a fairly minor step after you find out a little bit about photovoltaics," says Parrish.

As more and more ranchers lease grazing land, the portability of a PV system is a real advantage. Even systems that are not mounted on trailers can be moved without much trouble.

Buol's system has been operating for two seasons now with no real problems. According to Buol, "You just pull this up to the well, tie it up to the pump rod, and pump the water just like the windmill did. It's pretty handy."



CAP INTERNATIONAL

*Far from utility power lines, this portable PV pumping system pumps water from a fenced pond to a clean watering trough for cattle.*

PUMPING WATER

# PV PUMPS SURFACE WATER TO A TROUGH

*Eastern Irrigation District, Alberta, Canada*

## How it works

PUMPING WATER from ponds and streams to a cattle trough protects the water source and keeps the cattle healthier. The PV panels charge a bank of 6 deep-cycle batteries that power a centrifugal pump floating on the pond. A charge controller protects the batteries from overcharging or undercharging. The batteries allow water to be pumped day or night as cattle drink. When the cattle drink from the trough, a float switch activates the pump. The system pumps about 9,600 gallons (U.S.) per day to serve up to 550 cattle. A tracking mechanism (operated by expansion and contraction of freon) points the panels at the sun, which makes the system work with fewer panels than would be needed without tracking.

## How it came about

Preserving clean water supplies becomes more important each year with landowners and legislatures across North America. In Alberta, Canada, field manager Bob Hale was looking for a way to keep cattle from ruining Eastern Irrigation District's dugout ponds. By walking into the shallow ponds, the cattle would muck up the water and then refuse to drink it. Ranchers would have to move their herds, even though the grass was still plentiful.

One way to preserve stream banks and watering holes is to keep cattle out of the water and pump water to a drinking trough instead. Since Eastern's 600,000 acres of grazing land are far from utility power lines, Hale decided to try a PV-powered pump on a pond that serves 550 head of beef cattle. The pond measures 80 feet by 180 feet and is about 14 feet deep.

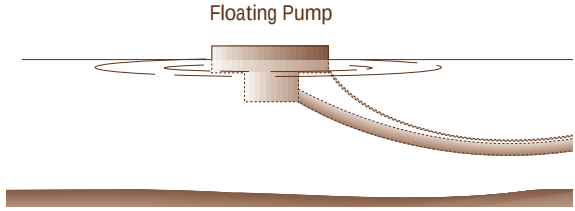
"It works good—excellent, really," Hale says about the PV pumping system. "We got it last spring and used it all summer until October. Then we shut it down and took it inside for the winter." Hale is pleased with the results. "This way we are able to keep the cattle in the fields longer and utilize the grass better because they have the clean water."

## Table of System Specifications

| | |
|---|---|
| Rated power: | 288 watts |
| Operating voltage: | 24 volts dc |
| Storage: | Battery capacity: 6 batteries; 300 amp-hours |
| Battery reserve (from full charge): | 2.5 to 3 days |
| Total cost of PV batteries, controller, and pump: | $4,800 |
| Estimated cost for utility connection: | Not an option, too far |
| Maintenance: | Take up and store in winter. Clean pumping components. Maintain batteries. |

## Contact about case study

Canadian Agtechnology Partners (CAP)
5037 50th Street, Suite 105
Olds, Alberta, Canada T4H1R8
Sandy Harvie: 403-556-8779
Fax: 403-556-8779



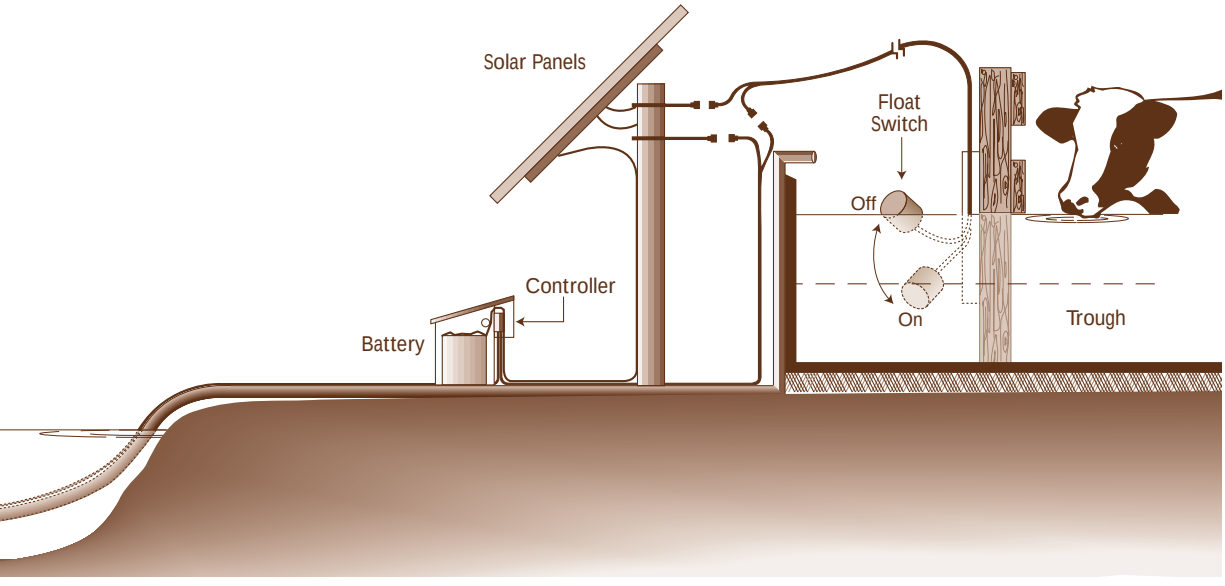
For times when they need to move the cattle, Hale decided to make the system portable. “We put the whole system on a trailer, so now we can pull it around from one dugout to another, he says. “We just built a trailer and put the batteries and the panels and everything on it so we can just move from one field to the next.”

When asked if he would recommend solar-electric pumping systems based on his experience, he answers, “We have three more coming this spring.”

CAP INTERNATIONAL

EASTERN IRRIGATION DISTRICT

*With plenty of clean drinking water, these cattle and calves grow faster and stay healthier than when they wallowed in their water supply. The PV pumping system brings water from the fenced pond to a metal watering trough. The concrete slab gives firm footing for cows and calves.*



PUMPING WATER

# Utility supplies electricity from the sun

*Northwest Rural Public Power District, Nebraska*

## How it works

RENTING PV PANELS to ranchers can save the utility and the customer money over what it would cost to build a new power line. The utility owns the six 56-watt PV panels. The rancher owns everything else. This pumping system operates at 46.7 volts and develops between 1/4 and 1/3 horsepower to run a submersible well pump. The system pumps up to 4,500 gallons per day from about 40 feet to serve some 80 cattle. The PV panels are mounted on a trailer that can be moved to other wells with the cattle.

## How it came about

When available, electric power for pumping water is the first choice of ranchers Yvonne and Bill Mooney. They want a reliable water source for their pedigreed Salers, Angus, and Aubrac breed cattle. But most of their wells are far from utility lines and are serviced by windmills dating back to the 1920s. These old windmills are less than ideal for modern ranching. "In the summer, we usually get two or three weeks of very little wind when you need the water the most, when it is hot," explains Yvonne Mooney.

JERRY ANDERSON, NORTHWEST RURAL PUBLC POWER DISTRICT

*When the windmills wear out, these ranchers are switching to solar-powered pumping for low maintenance and high reliability.*

So when it came time to replace an old windmill that was 4 miles from a power line, the Mooneys looked at all the options. A new windmill would have the same drawback as the old one during calm periods. In addition, a windmill would be a fixed installation. Like other ranchers, the Mooneys like to move their cattle to the best pastures. PV has the advantage of being portable if they wanted to move the herd.

The biggest advantage of PV for the Mooneys was that the utility would own the panels and simply charge them a rental fee. "We felt that it was better to go with the utility-owned system. It was much more feasible for us to use their panels and have the utility take care of them," Yvonne Mooney remembers. "They put them together and set them up for us."

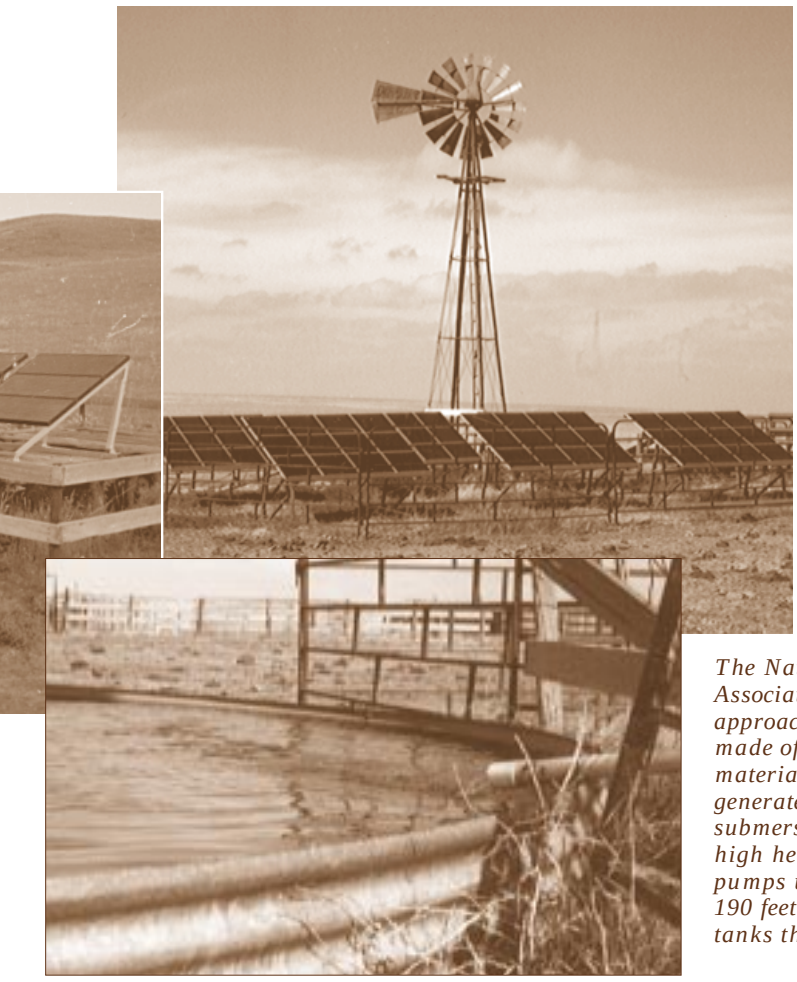
The PV-powered pumping system has worked out well. "We've had this one going on 5 years, and we're real pleased with it," say the Mooneys. They are so pleased, in fact, that they have ordered another system for a new well they are planning. This time they will buy the pump from the utility, but will arrange again to rent the PV panels.

## Table of System Specifications

| | |
|---|---|
| Rated power: | 336 watts |
| Operating voltage: | 46.7 volts dc |
| Storage: | No batteries; stores water in tank |
| Total cost of PV system (paid by utility): | $2,650 |
| Monthly payment to utility for this service: | $24.32 |
| Estimated cost for utility connection: | $10,000 x 4 miles = $40,000 |
| Maintenance: | Included in monthly payment |

## Contact about case study

Northwest Rural Public Power District
Jerry Anderson
P.O. Box 249
Hay Springs, Nebraska 69347
1-800-847-0492



RICK HINRICHS, BOULDER, COLORADO

*The National Rural Electric Co-op Association sponsors co-ops to test new approaches like this one. These panels are made of a potentially low-cost type of PV material called thin-film. The 12 panels generate 1.5 kilowatts to power a 3-phase submersible pump for applications requiring high head and high volume. The system pumps up to 3,600 gallons per day from 190 feet into a pipeline that serves two stock tanks three-quarters of a mile apart.*

# The Case for Utility PV Services

*K.C. Electric Co-op Association, Colorado*

## How it works

K. C. ELECTRIC INSTALLS PV SYSTEMS at the rancher's well to pump water for livestock. The utility owns and maintains the systems and charges the customer a flat monthly rate–$16 to $52 per month, depending on the size of the PV pumping system. The PV systems pump water the day after a storm takes out power lines and on the hot calm days of summer.

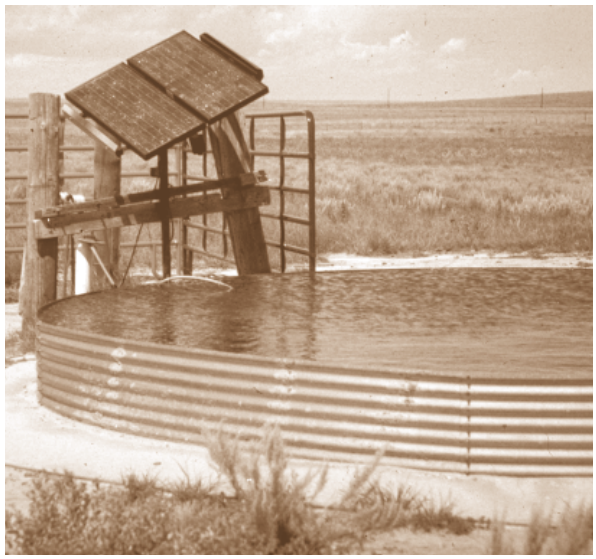
## How it came about

With power-line installation costs at about $10,000 per mile and 90 miles of lines serving only remote stock tanks, K.C. Electric Association in Hugo, Colorado, was looking for alternatives. These 90 miles of lines to stock wells cost the utility more in maintenance than could ever be recovered from fees. In 1988, winter storms broke 645 poles along these lines, and in 1989, K.C. lost 1000 poles to winter storms. The prospect of extending more lines like these to new stock wells encouraged K.C. to study using solar instead.

The utility began a pilot project that moved a mobile solar pumping system from one well to another on ranches. Once ranchers saw how well it worked they did not want to give it up!

Ranchers find that PV pumping is more consistent for remote areas and is available anywhere in K.C.'s territory, no matter how remote the well. After seeing solar pumping in action, K.C.'s customers are buying it themselves, without any utility involvement.

## PUMPING WATER



K.C. ELECTRIC ASSOCIATION

*One of K.C. Electric's PV systems, this portable unit pumps up to 1.75 gallons per minute from a 60-foot well to keep a stock tank filled.*

About 40 utilities in the U.S. have joined together to improve the PV service they offer. Through the PV Services Network, Inc., utilities order the packaged systems they need, assure timely delivery, and enjoy quantity pricing. In parts of the country where utility lines are costly to maintain or have not yet been extended, offering PV services is the best alternative for the utility and the customer.

### COMPARING THE COSTS OF PROVIDING ELECTRICITY TO STOCK WELLS

| | New Utility Line [A] | | Solar Generating System | |
|---|---|---|---|---|
| Installed Cost [B] | Description | Cost ($) | Description | Cost ($) |
| | Poles (26 per mile) | 7,081 | PV panels [C] | 2,600 |
| | Conductor (220 V AC, single-phase) | 2,100 | Single-axis tracker | 1,500 |
| | Transformer (10 kVA) | 480 | Balance-of-system (wiring, control, etc.) | 250 |
| | Meter | 40 | | |
| | Miscellaneous hardware | 1,000 | | |
| | Subtotal | 10,701 | Subtotal | 4,350 |
| Operating Cost [D] | Description | Cost ($) | Description | Cost ($) |
| | Inspection & troubleshooting [E] | 207 | Inspection & troubleshooting [E] | 25 |
| | Transformer losses [F] | 17 | | |
| | Amortization [G] | 812 | Amortization [G] | 330 |
| | Subtotal | 1,036 | Subtotal | 355 |
| Total First-Year Cost | | 11,737 | | 4,705 |
| Levelized Annual Cost | 30-year lifetime assumed | 910 | 20-year lifetime assumed | 420 |

NOTES:
A = Service for a livestock pump one mile from an existing power line.
B = Costs include materials and labor.
C = PV power supply sized for 100-foot well depth and 1,500 gallons per day.
D = Annual costs.
E = Cost based on $25 per hour labor rate.
F = Cost based on no-load energy losses of 400 kWh per year at $0.043 per kWh.
G = Cost based on 30 years at 6.5%, which was K.C. Electric's blended rate.

Source: NEOS Corporation, Technical Assistance Report for K.C. Electric Association, 1991. Sponsored by Sandia National Laboratories.

*Utilities offer PV services because it saves money. This analysis performed by NEOS Corporation for K.C. Electric Association in 1991 shows that it makes sense to use PV for stock wells rather than run power lines to these small loads.*

### CONTACT ABOUT CASE STUDY

The PV Services Network, Inc.
165 S. Union Blvd., Suite 260
Lakewood, CO 80228
303-980-1969

# POWER FOR BUILDINGS

USING PV TO GENERATE electricity for buildings can make sense if utility power is farther than several hundred feet away from where it is needed.

*With PV there is no need for poles, wire runs, or transformers.* Simple PV systems for security and task lighting generate and use the electricity right where it is needed. For homes or ranches farther than 1/4 mile from the utility line, a whole-house PV system can be less expensive than extending the power line.

*PV systems require little maintenance.* Because PV-generating systems have no moving parts, maintenance is limited to visual checks and servicing batteries. They require much less maintenance than diesel generators, windmills, or batteries alone.

*Photovoltaics is reliable.* PV modules generate electricity in all types of weather.

# PV SUPPLIES ELECTRICITY FOR FARMSTEAD

*Southwest Oregon, on the Illinois River*

## How it works

THE PV SYSTEM WORKS together with a small hydro plant to supply all the dc and ac electricity for this old homestead. During the four wet months, the 4.5-inch micro-hydro turbine supplies most of the electricity. During the rest of the year, the 900-watt PV system keeps a battery bank charged. Some appliances use dc directly from the batteries. For ac appliances, an inverter converts the 12-volt dc power from the batteries to ac. The PV panels are mounted on a tracking mechanism that keeps the system pointed at the sun for maximum power output.

## How it came about

When Bob Maynard decided to live on the family homestead in 1987, he knew he wanted a better solution to their power needs. Eighteen miles from utility lines, the farm's inhabitants had always made do without continuous power. "If they did have electricity," Maynard says, "they would just run a generator two hours a day and do the laundry and all the chores requiring power. The rest of the time it was kerosene lights."

*Photovoltaic systems can provide electric power far from utility lines for everything from lights and refrigeration to computers, televisions, and well water pumps.*

While he was looking for alternatives, Maynard became interested in solar and hydro. "It turned out to be the only practical solution for us," he says. "We use photovoltaics about 9 months out of the year for all of our power." During those drier months, they use their small stream for irrigation on the farm. "For our three wettest winter months, we capture the water in a pipe to spin a miniature 4.5-inch turbine to generate our power."

"We have an average rainfall of more than 100 inches per year," observes Maynard, "yet we are able to get three-quarters of our power from solar." The homestead has all the conveniences that electricity provides—from a blender, breadmaker, and microwave in the kitchen, to a table saw and air compressor in the shop. Maynard also runs a custom communication center that includes cellular telephone, radio telephone, citizens band, and ham radio. In the summer, the PV generates more electricity than they need, so they installed a dc submersible well pump to supplement their springs.

The PV system has operated smoothly since it was installed in 1990. "We were

## Table of System Specifications

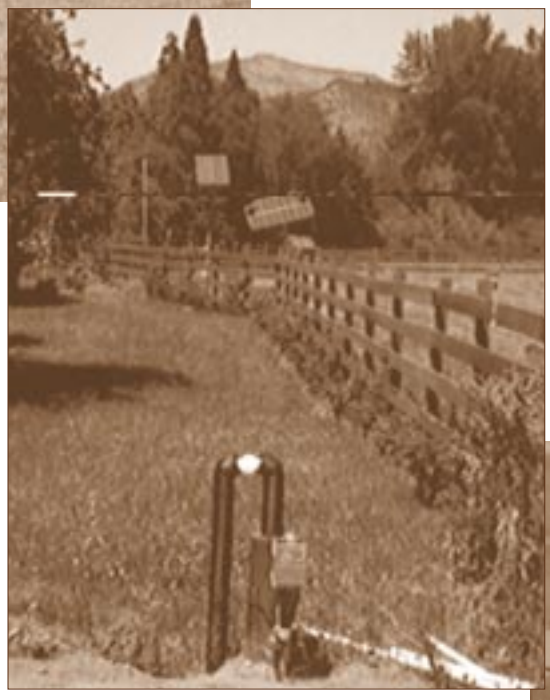
| | |
|---|---|
| Rated power: | 900 watts |
| Operating voltage: | 12 volts dc |
| Storage: | Battery capacity is 1750 amp-hours |
| Battery reserve (from full charge): | 6 days |
| Total cost of PV, batteries, and inverter: | $12,000 |
| Installation: | $2,000 |
| Estimated cost for utility connection: | $10,000 x 18 miles = $180,000 |

## Contact about Case Study

Energy Outfitters, Ltd.
P.O. Box 1888
136 S. Redwood Highway
Cave Junction, OR 97523
800-GO-SOLAR (467-6527)

completely surprised by how little maintenance is required," Maynard remembers. "I felt that this would be something that I'd be messing with on almost a daily basis." The only maintenance on the PV system has been to add water to the batteries every 2 or 3 months.

ENERGY OUTFITTERS, LTD.



ENERGY OUTFITTERS, LTD.


WARREN GRETZ, NREL/PIX04165

*An inverter like this one converts dc power from a battery bank to ac power for Bob Maynard's homestead. Ac power from an inverter will run almost any regular appliance designed to operate on utility power. Inverters consume about 10% of the power passing through them, so these losses need to be considered when designing an ac PV system. (Courtesy Jade Mountain)*

SUNELCO, INC.

*Electricity brings all the comforts of home to these houses far from utility power lines. Solar-generated electricity can be less costly than running diesel or propane generators because solar consumes no fuel and requires little maintenance. With no fumes or noise, PV complements these quiet rural settings.*

WARREN GRETZ, NREL/PIX04168

*PV can power bright security lights for fence gates, yards, or entries. Here, a small panel that can be mounted up to 14 feet away keeps a battery charged for this "smart" security light. The 20-watt halogen light is triggered by heat or motion and turns itself off when intruders leave. The light can operate for up to two weeks without sunshine. The cost is around $100. (Courtesy Jade Mountain)*

# AROUND THE RANCH

FARMERS IN ALL PARTS of North America are using PV to generate small amounts of electricity for important jobs around the ranch.

*Using PV is cheaper and easier than replacing batteries.* Away from power lines, small PV systems 3 inches to one-foot square can keep rechargeable batteries ready for action. This means fewer trips to out-of the-way corners of your property to replace batteries.

*PV systems are quiet.* With no moving parts, PV systems make no noise that would disturb people or animals. They can be a good alternative to diesel or gasoline generators.

*PV systems are tough and reliable.* Solar cells are durable and require little or no maintenance. They can withstand years of exposure to the weather.

AROUND THE RANCH

# PV KEEPS ELECTRIC FENCE WORKING

*Aristocrat Angus Ranch, Platteville, Colorado*

## How it works

THE 3-WATT SOLAR PANEL charges a 6-volt rechargeable gel cell battery. The battery operates the fence charger, which steps up the 6 volts to several thousand volts dc. The battery can operate the electric fence for up to 21 days without power from the solar panel.

## How it came about

For Don Curry at Aristocrat Angus ranch, electric fences are the most efficient way to keep cattle where he wants them. And PV-powered electric fencers are essential where there is no utility power.

"Yeah, I really believe in them," says Curry. "I can't get electricity to most pastures to use regular electric fence chargers." They tried battery-operated electric fencers, but as Curry explains, "The battery types don't last long, and it just doesn't pay to keep chasing batteries up there every other day or so. These solar chargers last all summer and longer. I've had three of them here for 3 years—same systems, same batteries."

"It really beats the 5-wire barbed wire fence," Curry says. "We use smooth wire so we can roll it back up again on a roller. We use just one hot wire on cows. When we've got calves, we use two because they crawl under if you don't."

WARREN GRETZ, NREL

*PV fence chargers supply plenty of "persuasion" to keep Angus bulls in their pens.*

The voltage in the fence depends on the length of wire served by each charger. The manufacturer estimates a 10-mile run will maintain about 3000 volts. Curry tailors the system to the situation. "We had about 5 miles out and were running about 4000 volts. Then we got some that are putting out 6000 volts that are short ones—like for the bulls, where they need more persuasion to stay where we want them." He estimates that a 100-yard run to keep cattle out of the river operates at 7000 volts.

Installation of the charger takes about 3 minutes according to Curry. "Just hang it up on a post, attach your ground wire and hot wire to it, and turn it on." For security, he brings the charger units back to the barn for the winter. "I take them in and cover them with dark blankets. When I need them, I set them out in the sun for 4 or 5 days before I use them again."

WARREN GRETZ, NREL

*PV fence chargers are easy to install. They can be moved from field to field with the cattle and will operate all winter long.*

## Table of System Specifications

| | |
|---|---|
| Rated power: | 3 watts |
| Operating voltage: | 6 volts dc stepped up to 7000 volts dc for short runs |
| Storage: | Battery capacity is 9.5 amp-hours |
| Battery reserve (from full charge): | 21 days |
| Total cost of PV: | $170 |
| Estimated cost for utility connection: | $10,000 per mile from nearest utility line |

## Contact about case study

Available from hardware and farm supply dealers in all 50 states and Canada.

Parker-McCrory Manufacturing Company
2000 Forest Ave
Kansas City, Missouri 64108
816-221-2000

# PV POWERS SPRAYER TO CONTROL FLIES

*Howard Kraus Ranch, Indiana*



## How it works

SPRAYING CATTLE with insecticide can help control flies. Every time a cow goes for mineral, this device sprays insecticide on her back. When the cow puts her head inside, a magnetic switch activates a timer. After seven seconds, a 12-volt electric pump runs for three-quarters of a second. This releases about 10 cubic centimeters of dilute fly spray in an 8-foot spread across her back. The 120-milliamp, 6-inch by 12-inch PV panel keeps a battery charged to run the pump anytime. If a calf is standing beside her, it gets a spray, too.

In the summer, Kraus fills up the sprayer and feeder about once a week, but the rest of the system requires no attention. He cleans the small PV panel at the end of winter, before filling up the sprayer for summer. Thanks to the PV cells on the top of the feeder, Kraus has never had a battery run down.

ALAN SHAEFFER,HAYWRAP CORP.

*The durable PV panel on this supplement feeder keeps the battery ready that powers the automatic fly sprayer.*

## How it came about

"Flies were a terrible problem for us," remembers Howard Kraus about his farm in Indiana. "I think half the cattle we bought that first summer came down with pink eye." Kraus tried to control the flies without much success. When he saw the combination mineral feeder and fly sprayer at a farm machinery show in 1992, he bought two on the spot. Four years later he has no regrets. "There is nothing that works as good as this," he says. "We haven't had a pink eye problem since we got the barrels."

On his 300-acre ranch, Kraus has two feeder/sprayers for about 100 cows. He hangs one barrel from a big shade tree. The other swings from a metal bar. "We picked the place where they hang out. On a hot summer day, sometimes there is a line waiting to get a spray."

### Table of System Specifications

| | |
|---|---|
| Rated Power: | 120 milliampere |
| Operating voltage: | 12 volts dc |
| Storage: | One battery; capacity is 7 amp-hours |
| Battery reserve (from full charge): | 60 days |
| Total cost of barrel supplement feeder/ sprayer with PV: | $289 |
| Supplement feeders without sprayer: | $65 to $140 |

### Contact about case study

Alan Shaeffer
Haywrap Corporation
Bloomsdale, Missouri
1-800-248-9727

The feeder/sprayer is being used on ranches across the United States and Canada.

AROUND THE RANCH

# PV POWERS A COMPRESSOR FOR FISH FARMING

*Alberta, Canada*

## How it works

A GOOD SUPPLY OF OXYGEN keeps fish healthier in winter and summer. Four PV panels power a compressor that pumps air into a 2.5-acre pond for rainbow trout. In the summer, two panels track the sun to power the compressor. In the winter, the other two fixed panels are added to get the most from the shorter winter days. A special hydraulic lock keeps water out of the freeze zone of the tubing in the winter.

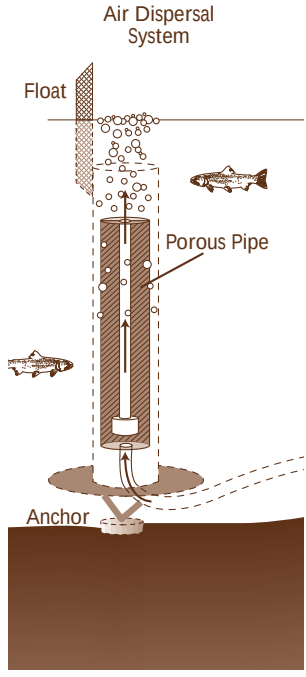
## How it came about

In 1988, Cal Evans decided to improve conditions in his trout pond by using an aerator. He wanted fish to survive the Canadian winter, and he wanted to reduce algae growth in the summer. Since utility power was about one mile away and Evans needed a system that would operate unattended, he decided to try solar.

"This works like a charm," Evans says. The compressor pumps air into the pond during the daylight hours. In the winter, it keeps a small section of water from freezing. But, more importantly, the fresh air pumped down into the water maintains oxygen levels for the fish in the winter and in summer.

"I put in about 400 fish in the spring and then we have fishing all summer, and smoke them for the winter," Evans explains.

The PV panels were shipped from the dealer about 120 miles away, and Evans installed the system himself in a few hours. He has worn out one compressor since 1988, but has had no problems with the PV panels. "Other than a little bit of window cleaner to clean off bird droppings or dust, I've done no maintenance," he says.




## Table of System Specifications

| | |
|---|---|
| Rated power: | 188 watts |
| Operating voltage: | 12 volts dc |
| Storage: | None |
| Tracker: | Passive tracker |
| Compressor: | A 12-volt, 8-amp compressor |
| Total cost of PV, tracker, compressor, and piping: | $2,880 |
| Estimated cost for utility connection: | $10,000 ($15,000 Canadian) |
| Special features: | Hydraulic lock keeps water out of freeze zone in pipes; air dispersal system increases oxygenation of pond water by creating very small bubbles. |

## Contact about case study

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Olds, Alberta, Canada T4H1R8
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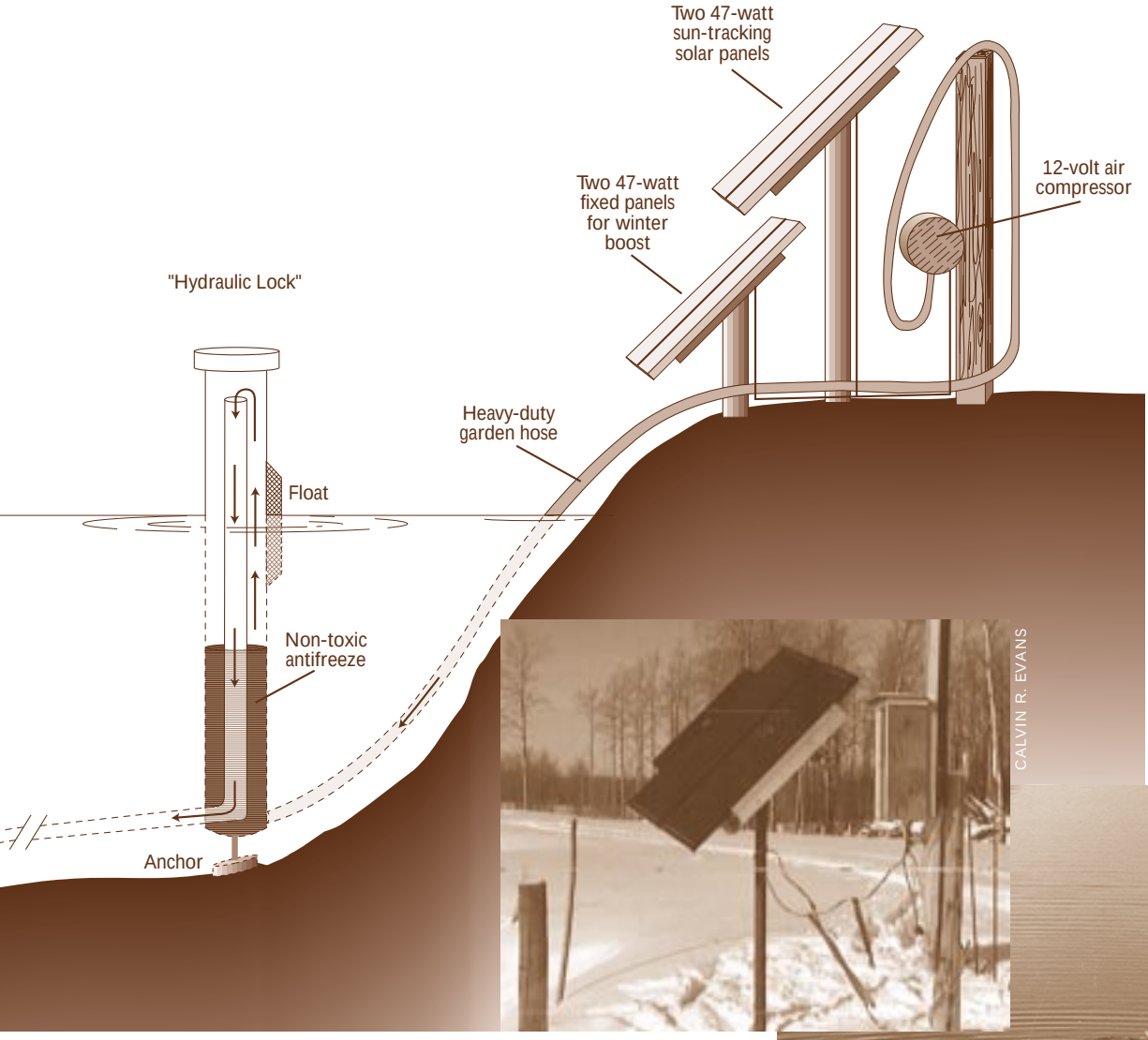




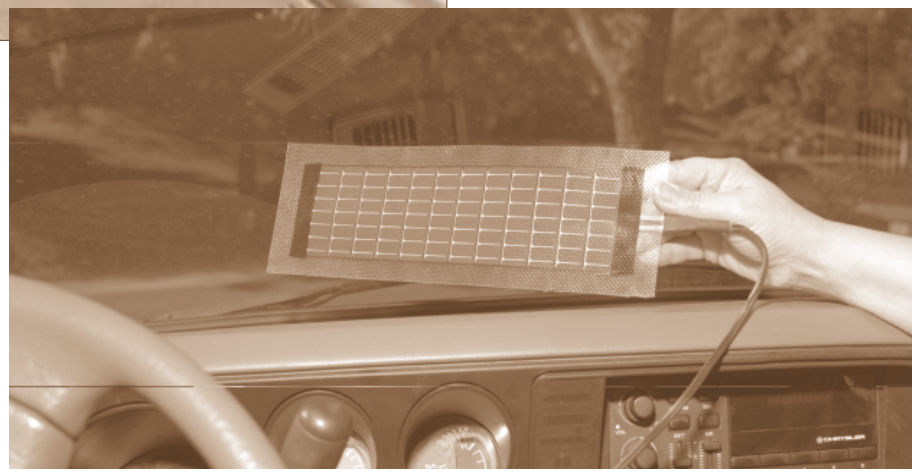

CALVIN R. EVANS

REGINALD HANCOCK

*Winter and summer, the PV-powered air compressor system keeps water quality good for rainbow trout like this 5-pounder being caught by owner Cal Evans.*

WARREN GRETZ, NREL/PIX04163

*Trailers and RVs used as living quarters on the ranch can include TV, microwave, and lights when PV is used to keep deep-cycle batteries charged. Advantages over gasoline generators include no fuel cost or nuisance, quiet operation, and low maintenance. Cost is around $900 to $1200. (Courtesy Camping World)*



WARREN GRETZ, NREL/PIX04164

*PV chargers can keep batteries fresh on farm equipment parked during the off season. This 1.5-watt PV panel plugs into the cigarette lighter to keep an automotive battery at full charge. The PV charger prolongs battery life and reduces maintenance. Cost is around $35. (Courtesy Jade Mountain)*

# WORKING WITH THE SUN

WHEN A LITTLE ELECTRICITY goes a long way, PV is often the best solution. Using electricity from the sun can be as simple as hanging up an electric fencer from the local feed and supply store. For most pumping applications it pays to go to your local drilling and pumping contractor or to your utility to see if they have experience with PV.

But the more you know about the parts of a solar electric system and how they work together, the more ideas you may have about how to put the sun to work. All PV systems include PV panels or modules, a support structure, and the load (pump, lights, motors, etc.). Some designs may also include a tracking system to keep panels pointed at the sun, batteries and controllers to store dc electricity, and an inverter to convert dc electricity to ac.

# Designing PV systems

DESIGNING PV SYSTEMS requires special expertise and experience. Lighting systems, electric fencers, and battery chargers all come as integrated kits designed by the manufacturer to work anywhere. But pumping contractors design PV pumping systems based on geographic location and pumping requirements. The PV components must be sized to provide enough power and voltage for the job. The trial-and-error approach can lead to unnecessary disappointments.

## How Many Modules?

Photovoltaic cells, from 2 to 5 inches across, are wired together to form rectangular panels called modules. Generally speaking, the larger the PV module, the more electricity it will generate. The more modules in a system, the more energy it will produce.

The number of PV modules needed depends on several factors. An important factor is the load or the amount of energy needed to run a pump or motor, or the amount of energy needed to keep a battery bank fully charged.

To figure the energy needed designers multiply the number of watts the load will consume by the hours per day the load will operate. For example, a 100-watt light bulb burning for 10 hours uses 1,000 watt-hours per day. Some designers recommend multiplying the total watt-hours you come up with by 1.5 to account for system losses and to provide a margin for error. For pumping applications, load will vary with vertical lift and pumping volume required. Most dealers present data for their products in tables that show how many PV panels are needed for various pumping conditions.

The next factor influencing PV system design is the hours per day of available sunlight. The number of PV modules times their output (usually between 50 and 75 watts) times the available hours of sunlight should equal the estimated daily electrical load. The hours of available sunlight vary with season, climate, and latitude. For pumping applications, this work has usually been done by the supplier and is incorporated into performance tables.

## The number of PV panels needed for various pumping conditions

| Quantity of 53-Watt Modules Required[2] | Capacity (in gallons per day) | | | | |
|---|---|---|---|---|---|
| | Total Vertical Lift (in feet)[1] | | | | |
| | 33 feet | 48 feet | 66 feet | 82 feet | 98 feet |
| 4 | 4610 | 1980 | 1580 | 990 | — |
| 6 | 6720 | 4040 | 2540 | 2075 | 1380 |
| 8 | 8830 | 6190 | 3655 | 2905 | 2320 |
| 9 | 9790 | 7185 | 4690 | 3340 | 2740 |

1 Total vertical lift (head) = distance from low-water level to outlet of discharge hose.
2 Output is based on 6 hours of good sun (solar day of 6 kWh/m²). If the systems are mounted on sun trackers, the capacity (output volume) can be increased by up to 30%.

Adapted from A.Y. McDonald Mfg. Co., Dubuque, Iowa.

*Tables like this are used by system designers to choose PV pumping components.*

## When does Tracking make sense?

The more directly the sun strikes the PV cells, the more electricity they produce. A tracking system can increase electricity production of a PV system up to 30% by changing the angle of the panels during the day to follow the sun. With tracking, fewer panels may be needed to meet daily loads. Adding a tracking system makes sense when it costs less than the panels it makes unnecessary.

## How Much Storage?

The energy generated by PV systems during the day can be stored for later use. For water-pumping systems it is easiest to store water in a tank during the day for the cattle to drink all night. The tank must be large enough to supply the cattle overnight and through several days of cloudy weather. The pumping system must be able to resupply the tank during sunlight hours.

When electricity is needed 24 hours a day, it can be stored in batteries charged by PV modules. Battery-charging systems come in all sizes. Very small PV panels of as little as 100 milliamps can keep an automotive battery charged and ready for use. A PV panel of 9 square inches can also keep a tiny sealed battery in action for years. On the other hand, a 1,000-watt PV system can keep a bank of 8 or 10 batteries charged for use at night in a home or for pumping water for cattle 24 hours a day.

Larger systems that use lead-acid batteries include a simple electrical device called a charge controller wired between the PV modules and the batteries. The charge controller protects the batteries from over- or undercharging. If the batteries are overcharged, in times of low electrical demand and high sunlight, they will dry out and be ruined. If the batteries are drawn down too low in periods of high demand and low sunlight, their life will be shortened.

CAP INTERNATIONAL

*Installing PV involves two kinds of work: structural and electrical. Structural installation of the panels must ensure that they are stable against wind and protected from livestock. The panels are layers of PV material sealed in glass or plastic with a frame and wire leads. Care must be taken not to flex the frames, which could crack the glass or break the seals.*

RICK HINRICHS

*For electrical installation, PV works like a dc power supply. All safety precautions and grounding procedures should be followed. Connections must be made to last the life of the system to avoid downtime, maintenance, and safety hazards.*

## AC or DC Electricity?

PV systems produce dc power that can run dc equipment directly or can charge batteries that power dc equipment. There are many dc appliances and tools available, but in some situations ac (regular household) power is a real advantage. To get ac power, designers add an electrical device called an inverter to PV systems between the batteries and the load. Inverters take dc power from a battery bank and change it into ac power. Ac power will run almost any regular appliance designed to operate on utility power.


WARREN GRETZ, NREL/PIX04167

*Inverters that convert dc power from batteries to ac power come in all shapes and sizes to meet the needs of today's farms and ranches. Converting the electricity supplied by PV systems from dc to ac allows owners to use all types of electrical tools and appliances. (Courtesy Jade Mountain)*

Computers, washing machines, TVs, and saws can be operated with a PV system that includes an inverter. Inverters consume about 10% of the power passing through them, so these losses need to be considered when designing an ac PV system.

Make sure components are compatible and meet safety requirements. Even 12-volt systems can develop up to 10,000 amps of current. Manufacturers of PV equipment offer warranties of 10 to 15 years. Installers also offer warranties and maintenance agreements.

## The Solar Workhorse

THE SUN'S ENERGY CAN OFTEN DO a job where and when you need it for the least cost, year after year. From panels a few inches on a side that charge a 7-amp-hour battery to PV modules that can power a conventional household, solar generating systems are sized to fit the job. If the job moves, you can move your PV generating system right along with it. And over the years, PV systems have proved to be extremely reliable on farms and ranches all over the world.

Each year brings more creative ways to save money with photovoltaics. More inventors are tapping PV to power their devices. More utilities are offering PV services because it is the least expensive way to bring electric power to some customers. And more manufacturers are packaging PV systems especially for the farm and ranch market, making it easier than ever to take advantage of the sun's energy.

## TO LEARN MORE ABOUT PHOTOVOLTAICS OR SOLAR-GENERATED ELECTRICITY:

U.S. Department of Energy
Energy Efficiency and Renewable Energy
Clearinghouse (EREC)
P.O. Box 3048
Merrifield, Virginia 22116
800-363-3732

National Center for Photovoltaics
NREL
1617 Cole Boulevard
Golden, Colorado 80401-3393
303-384-NCPV
Web page is http://www.nrel.gov/ncpv

National Renewable Energy Laboratory
1617 Cole Boulevard
Golden, Colorado 80401-3393
303-384-6469
Web page is http://www.nrel.gov/pv

Systems Assistance Center
Sandia National Laboratories
Division 6223
Albuquerque, New Mexico 87185
505-844-3698
Web page is
http://www.sandia.gov/Renewable_Energy/photovoltaic/PV.html

Home Power: The Hands-On Journal
of Home-Made Power
Ashland, Oregon

State Energy Office

Agricultural Extension Agent

## TO FIND PV EQUIPMENT SUPPLIERS:

Solar Energy Industries Association
122 C Street NW, Fourth Floor
Washington, D.C. 20001-2109
202-383-2600

Local Yellow Pages under Solar
or Recreational Vehicles Equipment

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The National Renewable Energy Laboratory, located in Golden, Colorado, is the nation s premier renewable energy and energy efficiency laboratory.

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NREL/BR-412-21732
January 1997