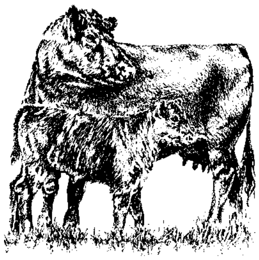

Solar Stockwater Systems

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Supplying adequate amounts of water for livestock at a reasonable price is a problem facing nearly all western ranchers. Inadequate water facilities is the number one cost associated with grazing on public lands. Inadequate and too few water developments is the main reason for poor distribution of cattle, uneven utilization of rangelands, and over utilization of riparian areas.

Most water developments on western rangelands are located away from reliable power sources. Ranchers have turned to windmills and labor intensive systems for pumping water, such as gas powered pumpjacks. Photovoltaic pumping systems are now an economical alternative for pumping stockwater on western ranges.

This fact sheet examines the use of photovoltaics technology, solar pumping system components, advantages of solar pumping, and how to choose and design a solar pumping system. Cost of pumping livestock water for shallow, moderate, and deep wells are variable (Balliette and Garrett 1990).

Photovoltaic Technology

(Photovoltaic) PV panels provide electricity directly from sunlight, with no moving parts. They provide modest amounts of cost-effective power, beyond the reach of utility lines. Hundreds of thousands of PV systems are used to provide electrical power in applications as varied as marine navigation buoys, mountaintop radio repeaters, pipeline and utility monitoring, electric fences, signs and yard lighting, boats, RV's, cabins, remote-site homes, and water wells.

Before 1980, high prices and lower efficiency of PV panels restricted their use primarily to the aerospace industry. Since then, technical advances and mass-production have brought PV prices down and improved efficiency.

At the heart of the technology is the solar cell made of silicon. Silicon is an inert dark-blue mineral, refined from sand. Sunlight causes electrons to jump from the negative to the positive side of the cell, generating electric power.

Solar cells are assembled into small panels called modules. A typical PV module consists of 36 cells, wired in rows behind a sheet of high-strength tempered glass. This laminated assembly is sealed weather-tight in an aluminum frame. For most stockwater pumping applications, a typical PV module is 5 square feet in size, weighs 14 pounds, and produces 50 watts of DC power at 15 volts.

The modules are assembled into a PV array by bolting them to a metal frame and wiring them together to obtain the desired voltage and current. An array of 10 50-watt PV modules can run a 1/2 horsepower DC or AC (with an inverter) electric motor.

Most PV modules use crystalline silicon solar cells, which have been in use since 1955. They have never been known to wear out. They resist hail storms and the most extreme climates on earth. Most have a 10- year warranty. Failures are exceedingly rare. Solar electricity, in terms of modules, is a one-time investment with a lifetime of return!

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Since photovoltaic power comes from sunlight, not heat, it is practical in cold as well as hot weather. In cloudy climates, PV arrays are sized larger to compensate for less sunlight.

Solar Pumping and System Components

Solar water pumps are specially designed to use solar power efficiently. Conventional pumps require utility lines or generators to supply power. Solar pumps utilize electric power from PV modules that varies as the sunshine varies. They must be designed to work effectively during low light conditions, at a reduced voltage, and without stalling or overheating.

Many solar pumping systems use positive displacement pumps that seal water in cavities and force it upward, thus maintaining their lift capacity even while pumping at slower rates. This differs from conventional centrifugal type pumps, including jet, submersible, and turbine pumps, which spin and "blow" the water up, and whose efficiency typically drops off at reduced speeds. Positive displacement pumps include piston and jack pumps, and diaphragm, vane, and screw pumps. Centrifugal pumps are more likely to be used for low lift or high volume systems, particularly to meet irrigation requirements.

Some solar powered pumps are fully submersible. Others use a motor above the ground to drive a submerged pump by means of a rod or shaft. Some are non-submersible, designed to push water uphill or to supply pressure. All are designed to use solar power most efficiently.

A controller is included with most solar pumps to prevent stalling in weak sunlight. This electronic device acts like an automatic transmission. It matches the PV array output to the pump motor under varying conditions of sunlight and load. The controller allows the pump to start and run with minimum sunlight, even if very slow.

Solar trackers tilt the PV array automatically to face the sun from sunrise through sunset. This extends the usable period of peak sunlight by as much as 55 percent. With more hours of sun exposure, a lower volume of water flow is required for a given daily yield. Thus, the size and cost of the solar array, pump, wire, and pipe may be reduced. The most common tracking mechanisms are fluid-driven by solar heat, rather than by electric motors. Extreme cold and wind may lower a tracking mechanisms' effectiveness. Under extreme environmental conditions, oversizing the PV array rather than installing a tracking mechanism may be reliable and more cost effective.

Storage of water or energy is important to solar pumping. On most days the system pumps more than the daily requirement in order to refill the system's water tank. Two to 10 days' storage may be required, depending on climate and pattern of water usage. In some systems, storage batteries provide an alternative to water storage by storing energy for pumping at night and during cloudy days. Batteries are then recharged by the photovoltaic array during daylight, though battery storage is more expensive and complex than storing water.

Solar pumping systems are available in the power range from 1/8 to 3 horsepower. Complete system costs may range from under $1,000 to several thousands, depending on water requirements, lift, and climate. Even some of the smallest systems can lift water from depths exceeding 200 feet, at low volumes. You may be surprised by the performance of a 1 gallon-per-minute pump. In one sunny day (10 hours) it will lift 600 gallons. That's enough to water 40 head of lactating cows with calves.

Advantages of Solar Pumping

Solar powered pumps require no fuel! They are quiet, pollution-free, and usually require little maintenance.

Solar powered pumps produce best during sunny weather when the need for water is greatest. Compared to windmills and gas powered pumpjacks, solar powered pumps are less expensive and much easier to install and maintain. They provide a more consistent supply of water, especially in critically dry times when there is plenty of sun but little wind. Properly designed systems can be installed in valleys, canyons, and wooded areas where wind exposure and accessibility is poor.

A photovoltaic array need not be placed close to the water source. To gain full exposure to sunlight, it may be placed some distance away from the pump itself, even hundreds of feet provided the electrical wire is sized properly.

Solar powered pumping systems are expandable. A pump may be installed with a half-sized PV array, and it will deliver half volume. Later, when more money is available or water requirements increase, the system may be expanded to full capacity.

A solar pump may be backup powered if necessary by an engine, a generator or batteries. In an emergency, small solar pumps may even be powered by the battery in a vehicle.

Low volume solar pumps offer unique benefits. They allow use of slow water seeps and marginal wells, even those producing less than 1/2 gallon per minute. Slow pumping reduces the cost of transferring modest amounts of water through long pipelines since small sized, inexpensive pipe may be used. Solar powered pumps can push water through miles of pipeline and up hundreds of feet of incline to where it is needed.

Small solar powered pumping systems are compact and light in weight. This minimizes freight and transportation costs. Many small systems are installed by hand. No special equipment or experience is required. They may even be portable, allowing them to be easily moved from one water source to another.

Should I Buy Solar Now, or Wait for Future Developments in Photovoltaics?

Higher Efficiency: Improvements in the efficiency of PV's mean only that more watts will be generated per square foot of module. Thus, a physically smaller solar array may be used to power your pump. This is not a critical factor in remote pump installations.

Lower Costs: Research and development in photovoltaics is aimed largely at producing cheaper PV cells using less durable materials. Today's crystalline silicon/tempered glass modules have proven themselves for decades. Even if cheaper modules become available, crystalline silicon will remain the technology of choice where long-term reliability is vital. Besides, PV modules account for less than half the cost of most solar pumping systems. The bottom line: Solar pumping is viable now.

How to Choose and Design a Solar Pump System

Choosing a pumping system is like ordering a suit of clothes. You need to state your measurements and your purposes. To help you request a design proposal or solicit a price quote, here is a list of the information you should specify.

Necessary Information for Solar Pump Design

- Well depth or description of water source.
- Depth to water surface: Does it vary? If so, how much?
- Yield of well estimated in gallons (or liters) per minute.
- Total vertical lift from water surface to storage tank or pipe outlet.
- Size of well casing (inside diameter).
- Quality of water: Is it clear, silty, or mineralized?
- Water requirements in gallons (liters) per day, according to season (design for most critical season).
- Application for water: Home? Livestock? Irrigation?
- Is pressure required?
- Can a storage tank be easily located higher than the point of use?
- Is the pump located near a home/battery system?
- Elevation above sea level determine suction limitations).
- Geographical location of system.
- Solar access: Is unobstructed sunlight available near water source? If not, how far away?
- Complex terrain? Draw a map or diagram.
- Describe existing equipment for pumping, distribution, storage, etc.
- Is this system to be the only source of water?

Table 1. Approximate total daily water intake (gallons) of beef cattle, NRC, 1984.

Animal weight (lb)	Ambient air temperature in °F* 40	50	60	70	80	90
Growing heifers, steers, bulls						
400	4.0	4.3	5.0	5.8	6.7	9.5
600	5.3	5.8	6.6	7.8	8.9	12.7
800	6.3	6.8	7.9	9.2	10.6	15.0
Winter pregnant cows						
900	6.7	7.2	8.3	9.7	—	—
1,100	6.0	6.5	7.4	8.7	—	—
Lactating cows						
900+	11.4	12.6	14.5	16.9	17.9	16.2
1,400	8.0	8.6	9.9	11.7	13.4	19.0

*Water intake of a given class of cattle is a function of dry matter intake and ambient temperature. Water intake is quite constant up to 40°F.

The Most Critical Step Is Design

The most critical step in designing a PV pumping system is matching water production of the pumping system to water requirements of livestock. Daily water requirements for cattle can be determined using the information in Table 1. Daily water requirements should be the basis for selecting a pump.

Keeping a pumping system simple is also important. PV pumping is best suited to remote areas. Complex designs that include numerous accessories are more prone to have failures and are thus not suited for remote areas. The goal for remote PV pumping is to pump all the water you can and store all the water not used.

A simple and effective design is shown in Fig. 1 (see next page). Wiring goes directly from the modules to the pump. The only accessories required are an on/off switch, controller (inverter if the pump is AC powered), and a fuse to protect the pump from lightening. Discharge is delivered to the top of a storage tank. This will aid in melting ice in the winter. The storage tank is connected to water troughs via a float valve and an overflow routed from the top of a storage tank. This is also important during cold weather pumping to both supply water to the troughs and to melt ice. Finally, an overflow should be included from the trough to a dirt tank or reservoir. Float valves can malfunction and a dirt tank will serve as secondary storage.

Installing a successful solar pumping system requires careful and conservative planning, and detailed knowledge of product and system design. Consult a reputable dealer. Your well driller and local pump suppliers may not yet be familiar with the technology, but may welcome the opportunity to serve you and your neighbors. If possible, contact two or more dealers and compare equipment and prices.

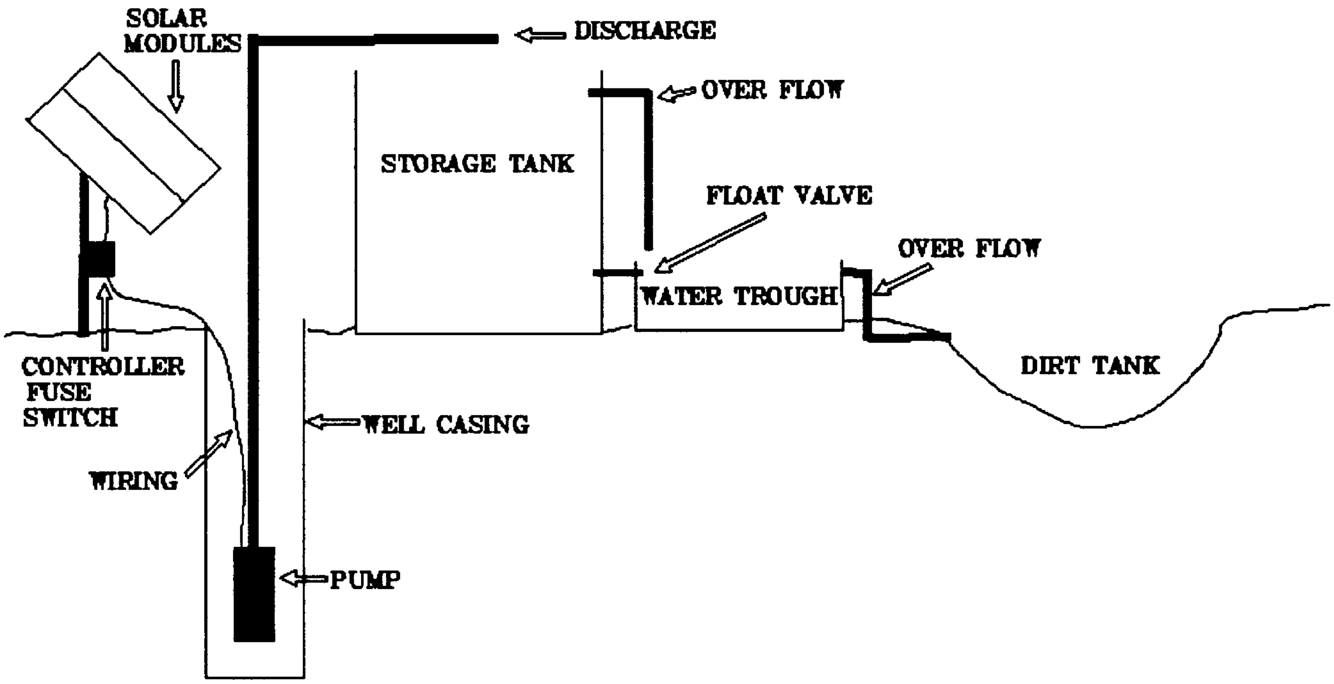

Fig. 1. A simple design for a remote livestock water pumping system.

Conclusion

Our lives depend on water. Water supply depends on pumping. If you value the long-term reliability and economy of your water supply, consider photovoltaic solar power. It's the proven energy source for the 1990s... and beyond.

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