Demonstration and Marketing of Photovoltaic-Powered Water Pumping Systems in New York State

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Summary

The purpose of this project was to provide New York State farmers with a cost-effective and dependable method for watering dairy or beef cattle in operations where grid-based electrical power is not available. While there are several possible methods for supplying water to remote pastures, solar powered water pumps may offer the best option in terms of cost and reduced labor. Three demonstration systems were constructed: 1) a pond in a beef grazing pasture at the Alfred State College Farm Laboratory in Alfred, NY; 2) a 230 foot well in a heifer pasture at the Alfred State College Farm Laboratory; and 3) a mobile unit used for demonstrations. Over the one-year study period, the performance of the pump systems was monitored. The systems were not used during the winter, requiring the storage of some of the equipment. The photovoltaic arrays did not need to be removed for the winter season.

In both applied demonstrations, water was pumped to an adjacent stock tank. Animals were excluded from the pond with a barbed wire fence. Float valves automatically shut off the pump when the tanks were full. There was no maintenance required over the one-year period.

The well unit pumped an average of 800-900 gallons per day during the summer months, well within the range of the manufacturer's specifications. During clear sunny days, the pump performed at its maximum advertised capacity (1.9 gallons per minute) over the course of eight hours of a summer day.

Our cost analysis concurs with other published studies that show that solar water pumps are more economical and less labor intensive than other options, such as wind, gas/diesel pumps, and trucking. In some instances with the correct topography and spring/pond location, ram pumps or gravity feed may be better options. In areas where water is supplied by a well and there is no access to the power grid, the solar pumps appear to be the best option.

Introduction

Presently, solar water pumps are used in the western United States as well as in many other countries or regions with abundant sunlight (e.g., Stokes et al., 1993; Hadj Arab et al., 1999). These systems, which store water in a reservoir rather than storing power in a battery, have a proven record of efficient, reliable and economical use in situations where water resources are spread over long distances, power lines are few or non-existent and fuel and maintenance costs are considerable. Currently, solar water pumps are not widely used in New York State and there is no literature reporting the use of these systems in the northeastern United States. In this proposed project, we demonstrate and measure the performance of stand-alone, photovoltaic-powered DC water pumping systems applied to livestock husbandry in western New York State.

Description of Installations

System Descriptions

Three water pumping systems were built for this project:

- A submersible pump in a 225 ft well (90 ft static water level) in a heifer pasture on the Alfred State College Farm Lab near NY Route 244.
- A floating pump on a developed pond in a pasture used for gazing beef cattle.
- A mobile demonstration unit to be used at workshops and outreach activities.

Table 1. Installation Specifications

225 ft. Well System	
output	1.4 - 1.9 gpm
	600 – 1000 gpd
Max lift	230 ft.
6"well $20/ft	$4,500
misc. drilling	$130
misc. fittings	$111
wire and Pipe	$300
well subtotal	$5,041
Shurflo 9300 submersible pump	$745
pump controller	$115
Two US-64 Unisolar modules	$842
Zomeworks passive tracker	$490
Misc.	$274
shipping	$135
pump/solar subtotal	*$2,601*
Labor	$1,100
total	**$8,742**

Pond System	
output	2 – 6 gpm
	600 – 1500 gpd
Max vertical lift	23 ft.
Sunmotor M3 floating pump w/ install kit	$1,295
controller	$115
US-42 modules	$578
Uni-Rac passive tracker	$565
tank float	$58
interconnect	$24
contr. enclosure	$30
wire	$16
mast & misc.	$358
pump/solar subtotal	*$3,039*
labor	$1,100
total	**$4,139**

The systems were designed and installed by Four Winds Renewable Energy of Arkport, NY. Table 1 shows the cost and claimed performance for both working units. Note that on the well-based system, the well drilling is over 50% of the cost and the components make up 30%.

Each unit pumped water into a nearby stock tank that was equipped with a float switch that shut off the pump when the tank was full. For both units, the PV array was installed on a eight foot steel mast with a passive tracker. The tracker uses the differential in heating of two, liquid-filled metal canisters as the sun moves over the sky to keep the panel pointed at the sun all day[1]. The panel mast and well-head were protected from the animals with steel gates. The pond, floating pump, and panels were fenced with barbed wire to exclude animals from damaging the equipment and entering the pond.

[1] See http://www.zomeworks.com/solar/trackrack/trackwork.html

Installation Location

The installation locations for the working units (well and pond) were determined based on the needs of the Alfred State College farm personnel as well as the educational needs of the project. The well system was sited along County Route 244 across the street from the farm. This location gives both high visibility to the project and provides water to a heifer pasture that was previously watered with a hose run across the road, which was both illegal and dangerous for farm workers.

The original plan for the well system was a site in an existing horse and cow pasture. However, the farm manager decided that a better location would be in a pasture that experiences two rotations of grazing from the beef cattle. The water was provided by a man-made pond dug from a spring. This resulted in a delay in the installation.

Performance Monitoring

Over the course of the year of the project, the performance of the pumps was measured as the volume of water pumped (each system had a water meter installed) over specific time periods. This included gallons per minute over short intervals as well as total gallons pumped over longer time periods. There were no failures of the equipment.

Because the working units were used to provide water for cows during the summer, we were unable to measure full performance over the entire period. The well system was oversized as only a maximum of ten cows were ever in the pasture at any time, so the full potential of the system was not met. When the cows were rotated out of the pasture, the pump was allowed to operate continuously and performance was then measured.

Due to the late installation of the pond, only short-term measurements were made. The farm staff has not re-installed the pond pump at the time of this report, so there are no long-term data for the pond pump. Therefore, most of the data reported below comes from the well unit. Data were taken when the pump could be run continuously, which was when the cows were rotated out of the pasture. When the heifers were in the pasture, they used on average 20 gallons/head/day during the summer months.

The rate of pumping in gallons per minute (gpm) is directly related to the amount of cloud cover. On a clear day, the pumping rate was consistently 1.8-1.9 gpm, the maximum that the pump is rated for, over the course of the days (excluding sunrise and sunset). This was measured between 9 AM and 5 PM on summer days, with lower rates during the dawn and dusk hours. The tracker enables the consistent pumping rate of the course of the day. On partly cloudy days, the midday pumping rate was 0.9 to 1.3 gpm when clouds obscured the sun. During severe cloud cover, such as rainy days, the pump would not operate (but is not needed).

The daily pumping rate in gallons per day (gpd) was evaluated as both a 24 hour measurement or as an average over a longer time period. Table 2 summarizes these values measured over several time periods. The highest values (1000-1120 gpd) were seen during clear summer days.

Table 2. Performance Summary

Time Period	**Range** (gpd)	**Avg.** (gpd)	**Comments**
8/23 – 8/27 2001	590-1100	834	Partly cloudy, no rain
9/20 – 10/5 2001	230-880	587	Variable; lowest values correlate with rainy days
5/7 – 5/20		457	Variable, mostly overcast
5/20 – 5/23		815	Clear to partly cloudy
7/16 – 7/18	837-1120	979	Clear to partly cloudy

Since we did not install an insolation meter, we cannot determine the precise correlation between pumping rate and incoming sunlight, but, we are working on quantifying the relationship between pumping rate and published daily insolation measurements.

Economic Analysis

In off-grid situations, the PV systems can be economically superior to other alternatives such as windmills and gas/diesel powered generators. Previous comparisons of stand-alone water pumping systems have shown clear economical advantages of the solar-powered systems. One study completed by the Bureau of Land Management at Battle Mountain, Nevada compared solar water pumping systems to generator systems. For one 3.8 gpm system with a 275 foot design head, the PV system cost only 64% as much over 20 years as the generator system did over only 10 years. This remote solar site also used only 14% as many labor hours. A Sandia National Laboratories study (Stokes et al., 1993) noted that photovoltaic pumping systems in remote locations would often be cost effective compared to generators, even with five times the initial capital cost. Low end diesel/gas generators, which are initially inexpensive, require consistent maintenance and have a design life of approximately 1,500 hours. Small to medium sized solar pumping systems often cost less initially than a durable slow speed engine driven generator. The key to solar's success is the low labor and maintenance costs relative to the other options. They are easy to install and the systems can be modular and the base system can be configured for a variety of environment-specific needs.

A quick cost comparison for the Alfred well solar system versus a gas generator and AC submersible pump (8 gpm) supports the previous studies. For this scenario, we assume a ten year period for an average 800 gpd over 180 days of use (Table 3). During this time, the PV array, controller, and tracker should require no maintenance. It is possible or likely that the pumps may fail during this time, but we assume that the likelihood for either system is equal and should cancel out in the analysis. It is probable that the gas engine will require maintenance every year or two and we assume one major rebuild. We assume two, half-day maintenance periods for the solar system. Using these assumptions, the solar system is about 60% of the cost over ten years.

If we calculate a cost associated with labor, then solar clearly has the advantage. If we assume one hour per day for a farmer to run the generator at $35/hour, that translates to almost $64,000 over 10 years. We assume both systems require a two-hour installation and removal per year.

Table 3. Comparison of Solar to Gas Generator

Type	Initial cost*	Fuel Cost	Maintenance	Total
Solar	$2,466	$0	$200	$2,666
Gas generator	$1,450	$2,605	$525	$4,580

*excluding the cost of well drilling

Outreach Activities

During the course of the year, we met with several groups in an effort to reach out to the agricultural community. These organizations include the Allegany County Soil and Water Conservation District (Fred Sinclair and Joe Orosz), the USDA-NRCS (Richard, Winnett, Don Wild, Robert Pederson and Abe Repine), and the Cornell Cooperative Extension of Steuben County (Carl Albers and Jim Grace). Don Wild took our group on pasture walks of several Allegany and Wyoming County grazing dairy and farms.

On September 6, 2001 we conducted a one-day workshop on the installation and use of photovoltaic-powered water pumps in agriculture. We showcased how these systems can be used to provide water to animals from a well and from a surface water source from installations at the Alfred State College Farm Laboratory. Windy Dankoff, owner of Dankoff Solar Products[2] and solar pumping expert, gave a tutorial on the technology and installation of PV-powered water pumps. The event was held at the Alfred State College farm and on the Alfred University campus. Approximately twenty people attended the entire workshop and fifty university students toured the demonstration.

In November 2001, the demonstration unit was displayed at the Innovations in Agriculture workshop hosted by the New York State Energy Research and Development Authority (NYSERDA) in Syracuse. We gave a talk showing images of the Alfred installations and giving preliminary data.

Information about this project has been posted on the website of the Center for Environmental and Energy Research at Alfred University[3]. We will continue to add to this site as we gain more information.

Discussion

Overall, the well system performed as expected, operating at maximum capacity during sunny days and at lower output on cloudy days. This highlights one of the advantages of

[2] http://www.dankoffsolar.com/
[3] http://ceer.alfred.edu/research_ext/PVPump/workshop.html

solar pumps: they work hardest when water is needed the most. The installation and seasonal dismantling of the system was straightforward and simple.

There are other options for providing water to grazing livestock in remote pastures, such as gas/diesel pumps, trucking, wind, ram pumps, or gravity feed (see Bartlett). Ram pumps and gravity feed require topographical relief and the gravity feed requires a water source that is physically higher than the pastures being used. The ram pump requires a running water source such as a stream or developed spring and will not work for a well system. In the previous section, we show that gas/diesel pumps are more expensive over a ten-year period and require more labor. Table 4 shows of the relative advantages and disadvantages of solar, gas/diesel, and wind.

Table 4.[4] Comparison of Solar, Fossil-Fuel, and Wind Systems

Pump Type	Advantages	Disadvantages
Solar	• Low maintenance • Clean • No fuel needed • Easy to install • Reliable long life • Unattended operation • Low recurrent costs • System is modular and can be matched closely to need	• Potentially high initial cost • Lower output in cloudy weather
Diesel (or gas) power systems	• Moderate capital costs • Can be portable • Extensive experience available • Easy to install	• Needs maintenance and replacement • Maintenance often inadequate, reducing life • Fuel often expensive and supply intermittent • Noise, dirt and fume problem • Site visits necessary
Windmill	• Potentially long-lasting • Works well in windy site	• High maintenance and costly repair • Difficult to find parts • Seasonal disadvantages • Need special tools for • installation • Labor intensive • No wind, no power

Over the course of this study, it was clear that there is a push from natural resource managers in support of prescribed grazing (also referred to as intensive grazing) for smaller dairy operations. Prescribed grazing has economic and environmental benefits that allow smaller farms to operate profitably and in an environmentally responsible manner. The availability and proximity of water in the paddock is critical to a successful grazing operation and in many cases, the solar system may be the best option.

[4] compiled from Kyocera Solar

It is impossible to make suggestions that cover all situations because each farm is different in terms of water sources, herd size, paddock layout, and topography. In flat regions and in instances where water is coming from a well, the solar pumps are the best option. Unlike our simple demonstration, a farmer may choose to pump water to a larger tank on a hill, and then supply water by gravity feed to a set of paddocks.

Short term benefits for dairy and beef farmers will be seen in the ease of installation (systems can be installed by the owner) and a reduction in the amount of time required for maintenance and refueling of generators. The PV pumps are easy to remove, transport, and store. Some long-term environmental benefits include allowing more remote pastures to be used, thereby allowing the implementation of shorter grazing times on other pastures. This would assist in the push towards intensive rotational grazing, in which grazing time is shortened to allow quicker foliage regeneration and reduce topsoil degradation (Rust et al, 1995). There is also the potential to improve regional water quality. Best practices suggest exclusion of animals from all surface water, but this is not always the case, particularly at smaller farms. PV water pumps can provide farmers with an economical and reliable method to pump water from nearby sources to stock tanks/troughs, resulting in a reduction in pollution and streamside degradation associated with livestock watering.

In addition to providing water for livestock, solar water pumps could be used for irrigation. Individuals from the Cornell Cooperative Extension have suggested that pumped water could be used to irrigate paddocks during July and August to assist in the recovery of forage during drought. Solar powered pressure pumps are commercially available for irrigation.

Conclusions and Future Work

The overall conclusion of this study is that solar powered water pumps can be practically and economically applied to animal grazing operations in upstate New York. The pump installed at the well performed as stated by the manufacturer, required no maintenance, and operated automatically over the grazing season. This demonstration uses relatively small pumps but there are larger pumps that can pump up to 7000 gallons per day and be applied to larger applications. The wide array of sizes of these systems and the reduced costs and improvement in photovoltaic technology allow great flexibility for use of solar pumping in many situations.

This year, Four Winds Renewable Energy has orders from four farmers for solar pumping systems in western New York. A recent NYSERDA project funded to the Sullivan Trail Resources Conservation Development Councils and Steuben County Cornell Cooperative Extension will result in the installation of twelve solar pumping systems. In addition, Four Winds and Sinton will work as subcontractors to conduct workshops in New York state on installing solar water pumps and pond aerators.

Resulting Professional Presentations and Publications

Sinton, C.W. and McCarthy, C., 2002, Solar-powered water pumping can work in the Northeast, *Northeast Dairy Business*, April, 54-55.

Sinton, C.W., 2001, Demonstration of Photovoltaic-Powered Water Pumping Systems in New York State, Innovation in Agriculture Conference, Syracuse, NY, NYS Energy Research and Development Authority.

Sinton, C.W. 2002, Solar Powered Water Pumping in Support of Sustainable Agriculture, Keene, NH, Ann. Meeting of the Society for Human Ecology.

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Hadj Arab, A., Chenlo, F., Mukadam, K., Balenzategui, J. L., 1999, Performance of PV water pumping systems, Renewable Energy, v. 18, no. 2 (October) p.191

Bartlett, B, Watering Systems for Grazing Livestock, Michigan State University Extension, 24 pp.

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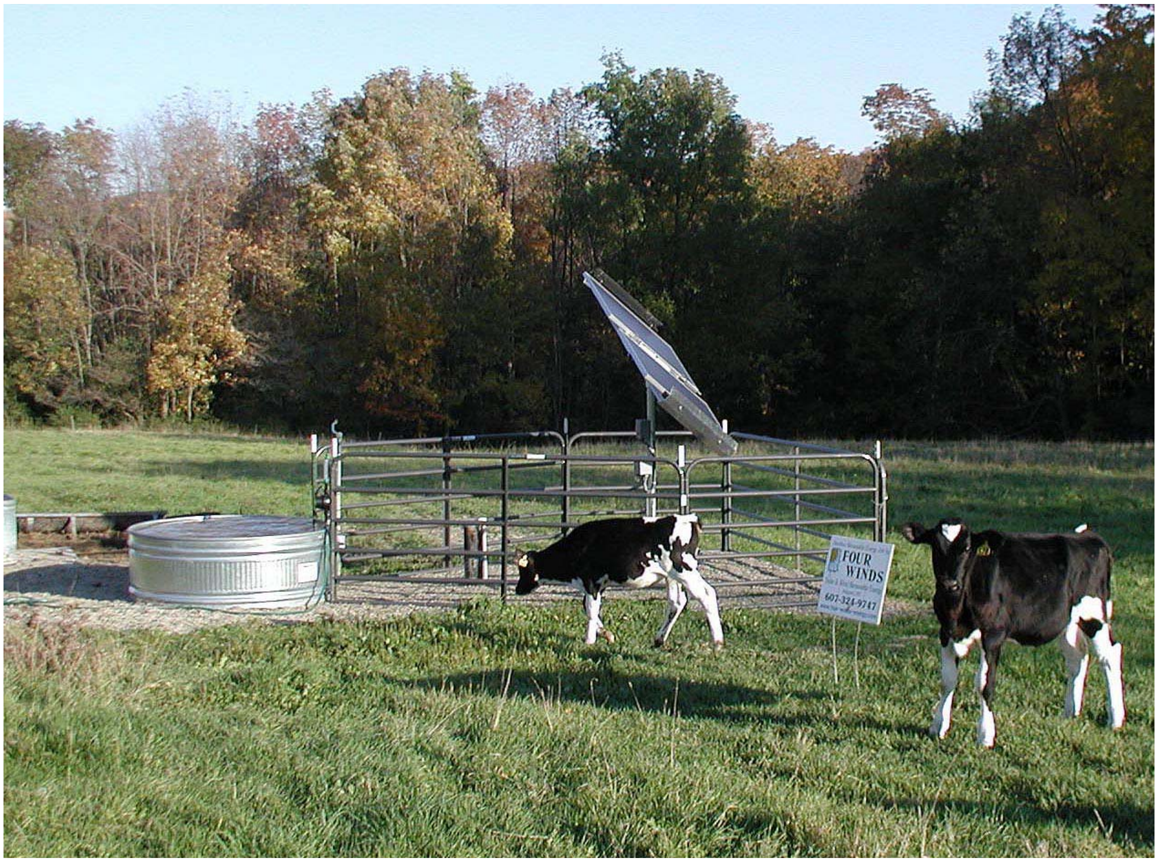
Rust, J. W., Sheaffer, C. C., Eidman, V. R., Moon, R. D., Mathison, R. D., 1995, Intensive rotational grazing for dairy cattle feeding, American Journal of Alternative Agriculture, v.10 (4), p.147

Stokes, K., Saito, P. and Hjelle, C., 1993, Photovoltaic Power as a Utility Service: Guidelines for Livestock Water Pumping, Sandia National Laboratories report SAND93-7043.



Young heifers near the well installation


Floating pump in developed pond pumps to a stock tank below