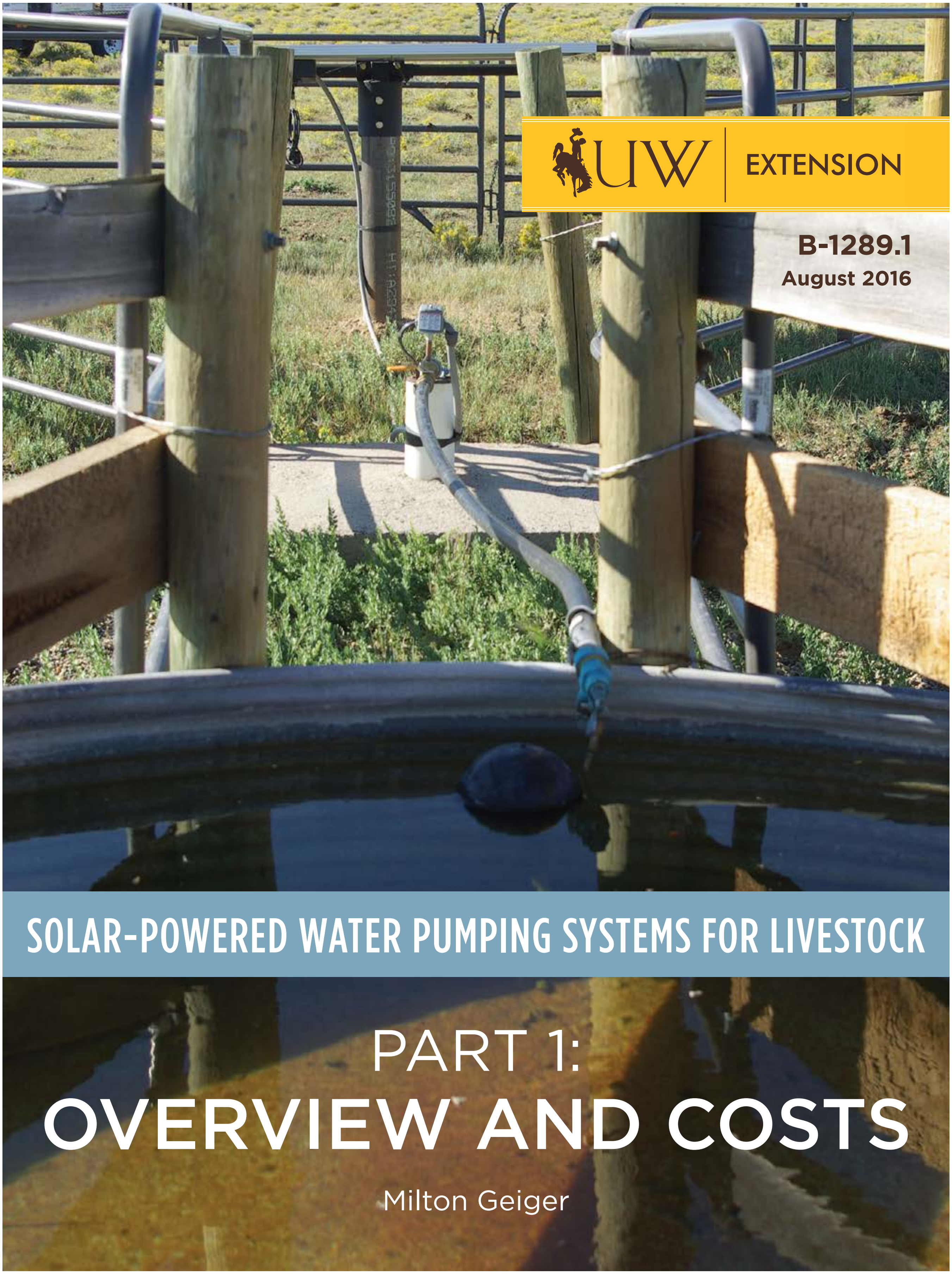

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SOLAR-POWERED WATER PUMPING SYSTEMS FOR LIVESTOCK

PART 1: OVERVIEW AND COSTS

Milton Geiger

http://bit.ly/2b22FJ4 • Steve Miler

SOLAR-POWERED WATER-PUMPING SYSTEMS FOR LIVESTOCK PART 1: OVERVIEW AND COSTS

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http://bit.ly/2bpviQ1 • Steve Miler

Western agricultural producers have many options for supplying water to livestock in remote settings. The iconic mechanical windmill provided the first, and still common, option for pumping groundwater in distant pastures. The extension of utility-provided electricity, often from local rural electric associations, offered a more reliable option. Gasoline, diesel, and propane generators provided further alternatives for using electricity to pump water. Most recently, the emergence of solar-powered water pumping systems (SPWPS), using photovoltaics (PV), has provided an additional opportunity for ranchers and small-acreage owners.

Part 1 of this bulletin series is the foundation for a two-part discussion of where and when SPWPS are most advantageous for Wyoming agricultural producers. Livestock water needs are diverse, with seasonality, well depth, flow requirements, proximity to utility-sourced electricity, and distance from the homestead impacting options. Ranchers and small-acreage owners need to know how SPWPS work and what factors influence their cost. Part 2 of the series, *SPWPS for Livestock: Where and when do they pay*? addresses scenarios where utility-connected systems, fossil-fueled generators, and SPWPS are the most cost-effective options.

Through these two UW Extension (UWE) bulletins, livestock producers and small-acreage can identify the general characteristics that define a profitable SPWPS opportunity and when other alternatives are preferable.

SPWPS background

SPWPS are not a new technology for Wyoming livestock producers. Wyoming ranchers and small-acreage owners began using SPWPS over 30 years ago. Declining costs and greater confidence in reliability and performance has led to SPWPS becoming increasingly common on Wyoming rangelands, often displacing mechanical wind pumps. With statewide access to low-cost PV panels, direct current pumps, and qualified installers, SPWPS is poised for further adoption by Wyoming's livestock producers.

SPWPS are used to pump groundwater or surface water for livestock and wildlife in remote, off-grid settings. SPWPS explored in this UWE bulletin series are not connected to the electrical grid (i.e., grid-tied).

WHAT ABOUT PV-POWERED IRRIGATION SYSTEMS?

Although possible to power low-pressure irrigation systems with SPWPS, irrigation applications in Wyoming are rare. Irrigating fields typically requires large quantities of seasonal electricity, which makes PV prohibitively expensive. Locations using gasoline or diesel generators can potentially reduce fuel consumption using PV, but this UWE bulletin series does not explore this option.

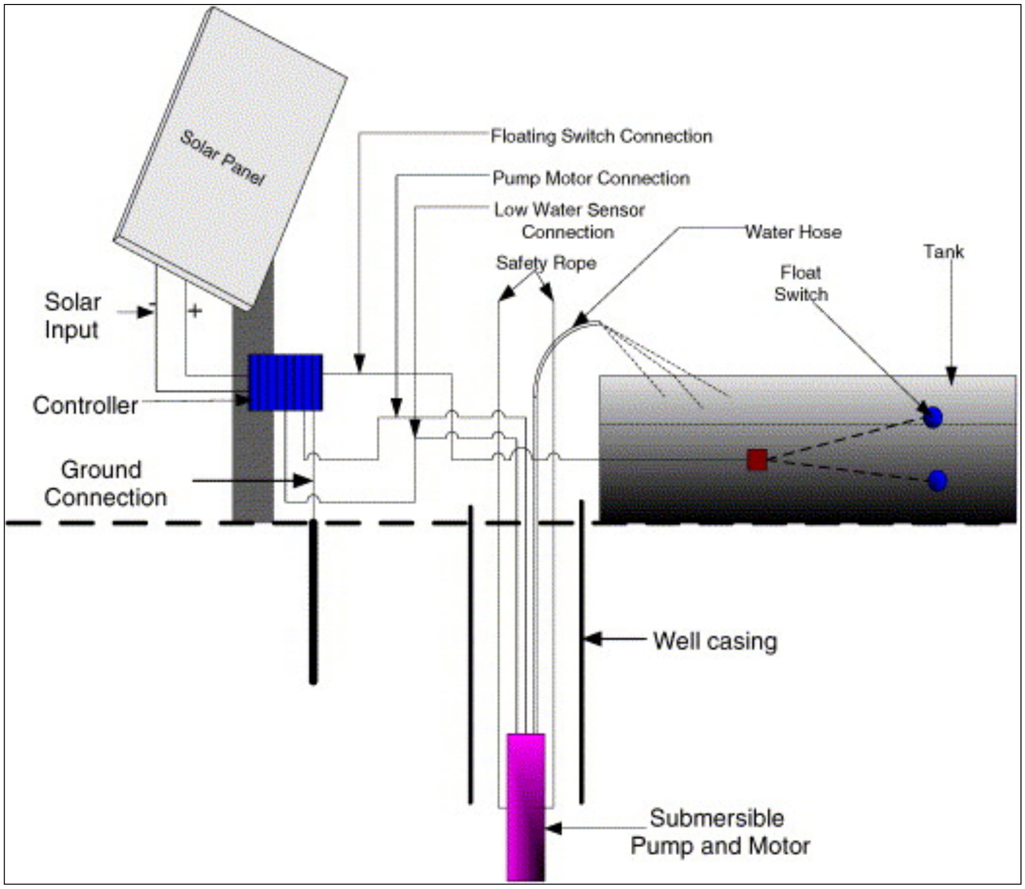

Figure 1: Schematic diagram of a SPWPS (Source: University of Wyoming Meah et. al 2008)

SPWPS use sunlight to produce electricity, which is then used to pump water (Figure 1). PV panels produce direct current (DC) electricity, but unlike in grid-tied settings, no inverter is required to change DC to alternating current (AC). Grid-tied (e.g., residential) applications require inverters because our appliances and electric-grid use 60 hertz AC electricity. In SPWPS, PV directly supplies electricity to a DC pump, increasing efficiency and reducing costs. SPWPS do not require batteries, as pumped water held in a tank efficiently stores energy. With no inverter or batteries, SPWPS are among the simplest application of PV.

Pumping groundwater is the most prevalent use of SPWPS, often providing the sole source of water in remote rangelands. Surface water installations are also becoming increasingly common, as land managers seek to encourage livestock to disperse from riparian areas.

Flow and pumping depth determine pump type (diaphragm, helical rotor, etc.). SPWPS can be used to pump water from depths exceeding 1,000 feet, allowing commercially available DC pumps and PV panels to serve most water pumping situations.

Numerous publications explain SPWPS technology, site selection, operation, and system design. Colorado State University Extension's *Solar-powered Groundwater Pumping Systems* and New Mexico State University Cooperative Extension Service's *Designing Solar Water Pumping Systems for Livestock* offer excellent introductions to SPWPS. In addition, New Mexico State's *Solar Water Pumping Design Spreadsheet Version II: Instruction and User Manual* and the USDA Natural Resources Conservation Service's Technical Note No. 28 *Design of Small Photovoltaic (PV) Solar Powered Water Pump Systems* allow for highly detailed sizing and site analysis.

Importance of solar resource

As we estimate costs for SPWPS, the location of our example matters. Wyoming's overall excellent solar resource varies throughout the state (Figure 2).

The quality of resource dictates how many solar panels are required to produce the energy needed by the water pumping systems. For example, a standard 200 watt PV panel, tilted at latitude (41° in Laramie and 45° in Sheridan) and facing due south, will produce an average of

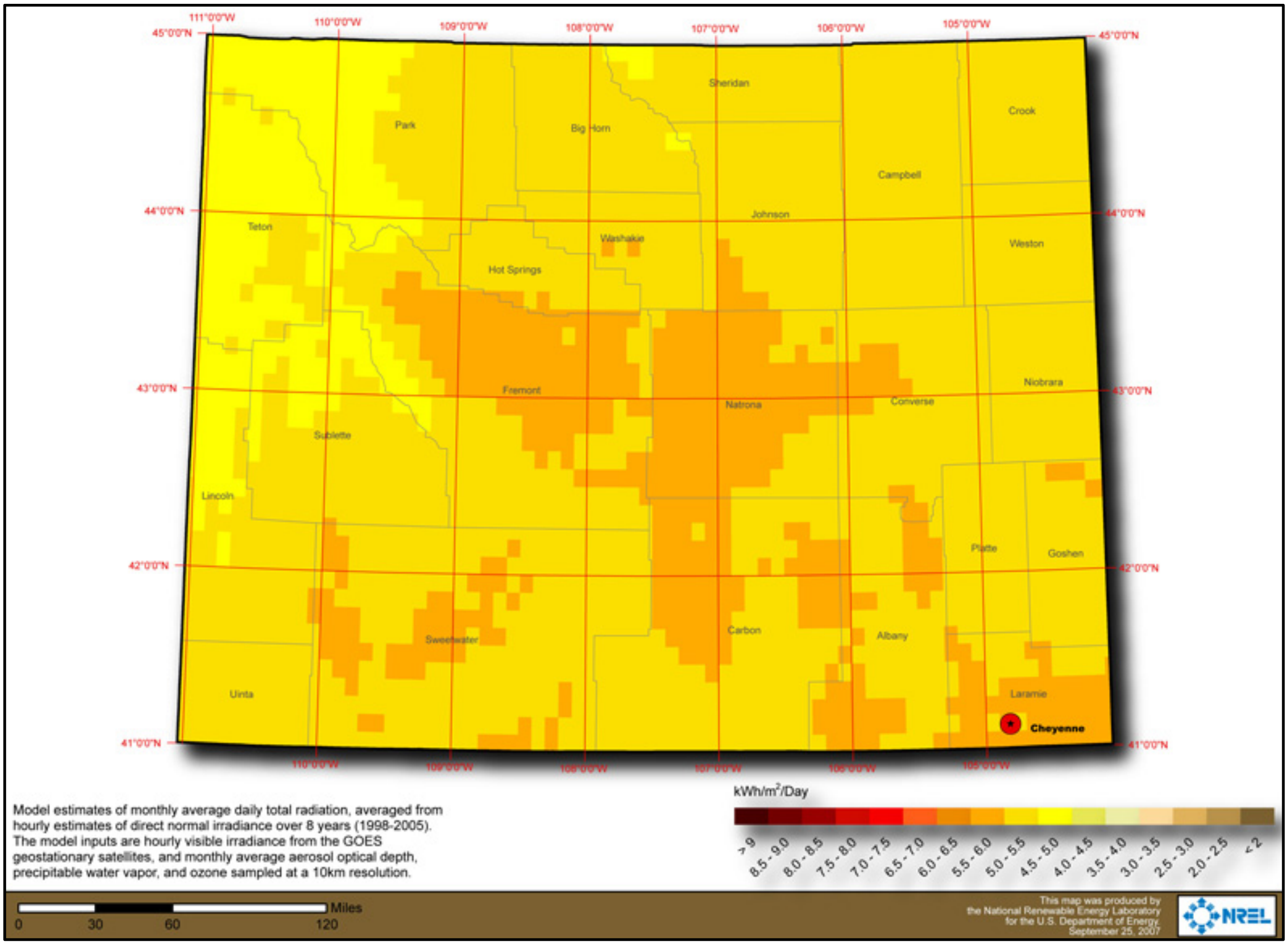

Figure 2: Wyoming global solar radiation at latitude tile – Annual (Source: National Renewable Energy Lab)

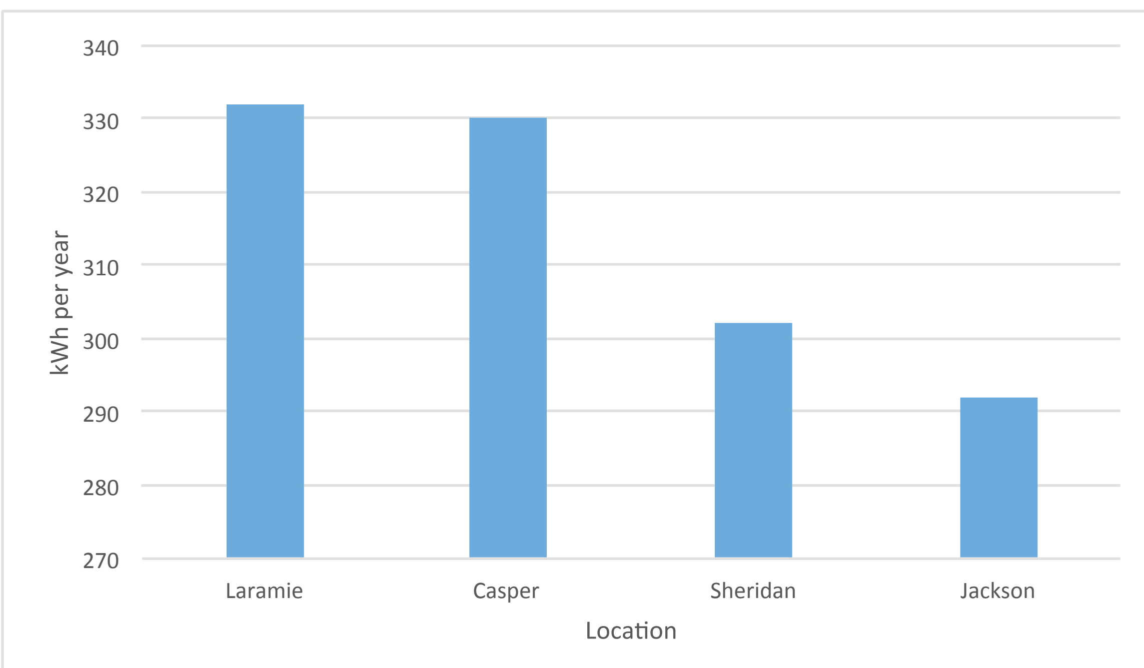

Figure 3: Estimated production of a 200 watt solar panel fixed at latitude (Source NREL PVWatts)

System characteristics	Required Measure	Unit
Total dynamic head		feet
Water required		
Summer		gallons per day
Fall/Spring		gallons per day
Winter		gallons per day
Duration of use		days

Figure 4: The required system parameters for costing SPWPS

332 kWh per year in Laramie and 302 kWh per year in Sheridan (Figure 3). Both are considered relatively robust solar resources, as a similar installation in Michigan (same latitude as Sheridan) would produce only 245 kWh.

How much do SPWPS cost to install?

The cost of SPWPS varies widely, as site-specific issues strongly influence final installed cost. Three principal factors affect system costs:

1. Total dynamic head,
2. Required water production (flow-rate),
3. Season of operation.

WHAT IS TOTAL DYNAMIC HEAD (TDH)?

TDH is the total equivalent height that water must be pumped, including friction losses. Friction loss is chiefly a factor of pipe size, pipe material (some are smoother than others), and the number of bends, turns, or valves.

Simply, a system requiring a larger pump and more PV panels will be more expensive. Also, the need for production during the short days of winter increases the required number of PV panels as opposed to a seasonal, summer system. Figure 4 displays the principal parameters for determining the cost of SPWPS.

Knowing these system characteristics allows for a calculation of the amount of energy needed by the system to pump water. The system requirements permit sizing of the solar panels and a comparison with a generator (fuel) and utility-sourced electricity (purchased electricity).

The system characteristics from Figure 4 inform the equipment and installation costs for different water options. Figure 5 shows the main components of SPWPS, utility-sourced, and generator water pumping systems.

The cost of the installation, especially for SPWPS, is influenced by the federal, state, and local incentives. The primary incentives are federal programs (Table 1).

Equipment	Price ($)
SPWPS	
PV array and wiring	
PV support structure	
DC Pump	
DC Pump controller	
Installation	
Utility-sourced	
Distribution line extension*	
AC pump	
AC pump controller	
Installation	
Generator	
Generator	
AC pump	
AC pump controller	
Installation	

Figure 5: Equipment and installation costs for a SPWPS, utility-sourced and generator water pumping system

Table 1: Business and agriculture incentives for SPWPS

Name	Description	Eligible technologies	Expiration date
Business Investment Tax Credit (BITC)	30 percent of installed cost (through 2019); 26 percent (2020); 22 percent (2021)	Solar PV, controls, and installation only (no pumps)	12/31/2021 (reduces to 10 percent in following years)
Modified Accelerated Cost-Recovery System (MACRS)	5-year depreciation schedule with bonus deprecation	Solar PV, controls, and installation only (no pumps)	None
USDA - Rural Energy for America Program (REAP)	25 percent grant	PV equipment and installation only; Minimum project size of $10,000	N/A – Program funding is uncertain
USDA – Environmental Quality Incentive Program (EQIP)	Grant program for agricultural producers; amounts vary	Selectively available PV and pumps	N/A – Program funding is uncertain

Notes: MACRS also includes special renewable energy system bonus depreciation. Equipment put in service before January 1, 2018, can qualify for 50 percent bonus depreciation. Equipment placed in service during 2018 can qualify for 40 percent bonus depreciation, and equipment put in service during 2019 can qualify for 30 percent bonus depreciation.

Not all incentives can be combined. For example, an agricultural producer could not use both USDA REAP and EQIP grants. Combining grants with the tax credits and accelerated depreciation is typically permissible, although receiving a grant can proportionally reduce the value of tax credits and deductions. The easily used BITC and MACRS lessen the cost of solar equipment (not pumps) by around 45-50 percent, as MACRS has a present value of roughly 15-20 percent of the installed PV equipment. The use of other federal grants and the existence of some local funds (e.g., Conservation Districts or electric utilities) can further lower the cost for SPWPS. Remember, an agricultural producer must have a tax liability to use the tax credits.

If a small-acreage owner does not operate a commercial enterprise with her/his livestock, then the Residential Renewable Energy Tax Credit could also be used. The tax credit is similar to the BITC at 30 percent, with declining values in 2019, 2020, and 2021. The tax credit fully expires at the end of 2021.

WHAT IS ACCELERATED DEPRECIATION AND WHY IS IT VALUABLE?

Accelerated depreciation schedules, such as MACRS, permit equipment to be depreciated more quickly than typical straight-line (e.g., 7, 10, or 20 years) methods. For example, a PV panel may be expected to last 25 years (thus practically depreciated over 25 years), but MACRS allows the panel to be financially depreciated in just 5 years. This likely provides a tax savings for agricultural producers who have a tax liability, as it reduces taxable income in the early years of system operation. Simply, accelerated depreciation does not increase the amount that can be deducted from taxable income, but it allows ranchers to get the tax savings sooner. Most ranchers would prefer money today as opposed to 25 years from now.

The number of factors that dictate the cost of a system can seem daunting. Before gathering detailed information, most agricultural producers appreciate a rule of thumb. For SPWPS, the following rough estimates are valid in 2016:

- Solar electric panels (PV array) and wiring –$1.00-3.00 per watt
- Support system (racking) – $100-800
- Controller (pump and float) – $200-500
- DC pump – $500-2,500

Per watt capacity is a standard term in the solar industry but is a strange term to many agricultural producers. For example, a common two-panel system (typically 400 watts of capacity) would cost $600-1,200 for the panels and racking. Although required for any type of livestock watering system, the highly variable cost of fencing, plumbing, overflow shut-off devices, storage tanks, and labor can also affect the cost of SPWPS. For example, a larger storage tank, to account for daily production variability, can be an additional cost for SPWPS compared with other water pumping options. Most extension livestock specialists recommend three days of water storage for PV water pumping systems. Similarly, more fencing may be required to protect the PV panels compared to alternatives (e.g., a utility pole or generator).

Applying the parameters shown in Figures 4 and 5 to a theoretical Kaycee, WY, installation results in the approximate costs shown in Table 2.

Table 2: Example equipment costs (excluding tanks and wells) for a fixed SPWPS installation in Kaycee, WY[1]

System size (100 feet TDH)	PV array and wiring	Support system	Controller	DC pump	Total cost
Small system (200 watts and 1,000 gallons per day)	$535	$250	$400	$892	**$2,077**
Medium system (400 watts and 2,000 gallons per day)	$785	$300	$400	$1,732	**$3,217**
Large system (900 watts and 4,000 gallons per day)	$1,466	$550	$400	$2,032	**$4,448**

[1] *From Jenkins, Thomas.* Solar Water Pumping Design Spreadsheet Version II: User Manual. *New Mexico State University Cooperative Extension Service Circular 671. 2012. Available from: http://aces.nmsu.edu/pubs/_circulars/CR671.pdf; Cost of PV without racking reduced to $1.50/watt from $2.50/watt based upon 2014 solar industry price reports.*

All systems are assumed to operate during the summer grazing season (May-October).

The design assumes the use of a SunPump brand DC pump. Other manufacturers, such as Dankoff, Grundfos, Lorentz, Robison, or ShurFlo, could also be substituted for the example. The estimated costs originate from New Mexico State University Cooperative Extension Service's *Solar Water Pumping Design Spreadsheet Version II.* No incentives, such as the Business Investment Tax Credit and Modified Accelerated Cost Recovery System depreciation, are included.

WHAT ABOUT A DEEP WELL?

As USDA Natural Resources Conservation Service and others provide incentives based on well depth, you may wonder what a deep-well SPWPS costs? Using the same New Mexico State calculator, a well pumping 1,200 gallons per day with 400 feet of total dynamic head would cost $5,965. The solar array would need to be 1,095 watts. Deeper wells are more expensive than shallower wells, but the decline in the price of PV panels has lowered the "sticker shock."

How much do SPWPS cost to operate?

The upfront costs are an important consideration for the initial evaluation of SPWPS, but the long-term operations and performance truly determine viability. Figures 6 and 7 shows the system characteristics and operating costs needed to compare SPWPS to utility-sourced electricity or generators.

Finally, four additional factors significantly influence the long-term operating costs of the respective systems: the discount, inflation, real energy escalation, and tax rates. The discount rate reflects the time value of money. If you spend $5,000 on a PV array, you cannot invest that money in something else. Alternately, if you borrow $5,000 to buy a PV array, your credit union or bank will charge interest on the

System characteristic	Measure*	Unit
Distance (round trip)		miles
Vehicle efficiency		miles per gallon
Site visit frequency		
SPWPS		per week
Utility-sourced		per week
Generator		per week
Labor required		
SPWPS		minutes per visit
Utility-sourced		minutes per visit
Generator		minutes per visit
Lifespan		
PV array		Years
Pump (AC and DC)		Years
Generator		Years
Utility connection		Years

** Includes selected UW Extension suggestions*

Figure 6: System characteristics that inform operating costs

loan. The inflation rate reflects changing prices over time. The real (above inflation) energy escalation rate is vital. In the last 10 years, electricity, gasoline, and diesel prices have increased at rates greater than inflation. The tax rate influences the value of some incentives, particularly MACRS-driven deductions.

Conclusion

Unfortunately, general estimates for SPWPS costs are difficult to provide due to unique site-specific characteristics. Total dynamic head, required flow-rate, and season of operation all significantly affect the installed cost of SPWPS. The cost of components can be estimated but only within relatively wide ranges. Thus, correctly evaluating SPWPS compared to utility-sourced electricity and generators requires agricultural producers and small-acreage owners to understand both how and where the respective system will function. Choosing the most cost-effective option requires spending the time to collect the necessary information shown in Figures 4-6. *Part 2: When and where do they pay?* provides tangible examples to help determine if SPWPS is right for anoperation.

To evaluate your water-pumping situation, please visit http://renewables.uwyo.edu or contact your local University of Wyoming Extension educator.

Input	**Price***	**Units**
Gasoline		per gallon
Diesel		per gallon
Utility-sourced electricity		per kWh
Utility-sourced base charge		per year
Maintenance		
SPWPS		dollars per year
Utility-sourced		dollars per year
Generator		dollars per year
Labor		Per hour

** Includes selected UW Extension suggestions*

Figure 7: Variable costs for SPWPS, utility-sources, and generator systems

Additional resources:

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